The following documents show the May 2012 Draft NGSS performance expectations grouped by topics.

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K.OTE Organisms and Their Environments

K.OTE Organisms and Their Environments

Students who demonstrate understanding can:

a. **Use observations and information to classify living things as plants or animals based on what they need to survive.** [Clarification Statement: To survive and grow, animals need food, water, and air. Plants need water, light, and air to live and grow.]

b. **Use observations to describe how plants and animals depend on the air, land, and water where they live to meet their needs, and they in turn, can change their environment.** [Clarification Statement: Examples of how plants and animals change their environment could include ants making anthills, plant roots breaking concrete, or beavers building dams.]

c. **Use observations and information to identify patterns in how animals get their food.** [Clarification Statement: Animals get their food by various means. Some animals eat plants, some eat other animals, and some eat both.]

d. **Provide evidence that humans' uses of natural resources can affect the world around them, and share solutions that reduce human impact.** [Clarification Statement: Examples of how humans' uses of natural resources can affect the world include cutting trees for lumber and paper products or discarding plastic bags and other waste that affects animal habitats. Humans can reduce their impact by recycling and avoiding littering.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Make observations to collect data which can be used to make comparisons. (a)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

- Use and share pictures, drawings and/or writings of observations. (c)
- Use observations to describe patterns and relationships in order to answer scientific questions and solve problems. (b),(c),(d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Read and comprehend grade-appropriate texts and use other media to acquire scientific information. (d)
- Critique and communicate information with others in oral and/or written forms using models, drawings, writing, or numbers. (d)

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. (a),(c)

ESS2.E: Biogeology

- Plants and animals (including humans) depend on the land, water, and air to live and grow. They in turn can change their environment (e.g., the shape of land, the flow of water). (b)

ESS3.A: Natural Resources

- Living things need water, air, and resources from the land, and they try to live in places that have the things they need. Humans use natural resources for everything they do: for example, they use soil and water to grow food, wood to burn to provide heat or to build shelters, and materials such as iron or copper extracted from the earth to make cooking pans. (a),(d)

ESS3.C: Human Impacts on Earth Systems

- Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things—for example, by reducing trash through reuse and recycling. (d)

Crosscutting Concepts

Patterns
Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (a),(c)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. Therefore, taking natural materials to make things impacts the environment. (d)

Connections to other DCIs in this grade-level: **K.WEA**

Articulation of DCIs across grade-levels: **4.PSE, 4.E, 5.MEE, 5.ESI**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.K.2 With prompting and support, identify the main topic and retell key details of a text.

W.K.2 Use a combination of drawing, dictating, and writing to compose informative/explanatory texts in which they name what they are writing about and supply some information about the topic.

SL.K.1 Participate in collaborative conversations with diverse partners about kindergarten topics and texts with peers and adults in small and larger groups.

SL.K.3 Ask and answer questions in order to seek help, get information, or clarify something that is not understood.

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others.

MP.7 Look for and make use of structure.

K.CC.6 Compare numbers.

K.MD.3 Classify objects and count the number of objects in each category.

K.SPM Structure and Properties of Matter

K.SPM Structure and Properties of Matter

Students who demonstrate understanding can:

a. Make observations that matter exists as different materials, which can be described and classified by their observable properties and their uses. [Clarification Statement: Observable properties could include color, texture, and hardness.]

b. Compare and share observations of solids and liquids at room temperature.

c. Plan and carry out investigations to test the idea that warming some materials causes them to change from solid to liquid and cooling causes them to change from liquid to solid. [Clarification Statement: Students could investigate substances like butter, chocolate, ice, cheese, or ice cream. Students should be able to have the opportunity to see that not all substances' phase changes with temperature.] [Assessment Boundary: Only a qualitative description of temperature should be used.]

d. Distinguish between opinions and evidence in determining whether objects in a given set occur naturally or are manufactured. [Clarification Statement: Examples of natural and manufactured objects could be a wooden dowel which has been made to be smooth and a tree limb which is not naturally smooth.]

e. Ask questions and share information about the natural materials from which human-made products are built. [Clarification Statement: Examples of natural and manufactured objects could be a wooden dowel which has been made to be smooth and a tree limb which is not naturally smooth.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.
- Ask questions about observations of the natural and designed world. (e)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
- Plan carry out investigations collaboratively. (a)
- Make observations to collect data which can be used to make comparisons (a),(b),(c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing explanations and designing solutions.
- Distinguish between opinions and evidence. (d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and progresses to evaluate the merit of ideas and methods.
- Critique and communicate information with others in oral and/or written forms using models, drawings, writing, or numbers. (b),(e)
- Record observations, thoughts, and ideas. (b),(e)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Different kinds of matter exist (e.g., wood, metal, water) and many of them can be either solid or liquid, depending on temperature. (a),(b),(c)
- Matter can be described and classified by its observable properties (e.g., visual, aural, textural), by its uses, and by whether it occurs naturally or is manufactured. (a),(d)

ETS2.A: Interdependence of Science, Engineering, and Technology
- People encounter questions about the natural world every day. (a),(b),(c),(d),(e)

ETS2.B: Interactions of Engineering, Technology, Science, Society, and the Natural Environment
- Every human-made product is designed by applying some knowledge of the natural world and is built by using materials derived from the natural world, even when the materials are not themselves natural—for example, spoons made from refined metals. (d),(e)

Crosscutting Concepts

Patterns
Patterns in the natural and human designed world can be observed, used to describe phenomena and used as evidence (a),(b)

Cause and Effect
Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes. (c)

Energy and Matter
Objects may break into smaller pieces, be put together into larger pieces, or change shapes. (e)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. Therefore, taking natural materials to make things impacts the environment. (d)

Connections to other DCIs in this grade-level: **N/A**

Articulation of DCIs across grade-levels: **2.ECS, 2.SPM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.K.2 Use a combination of drawing, dictating, and writing to compose informative/explanatory texts in which they name what they are writing about and supply some information about the topic.

W.K.7 Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them).

W.K.8 With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question.

SL.K.3 Ask and answer questions in order to seek help, get information, or clarify something that is not understood.

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others.

MP.7 Look for and make use of structure.

K.MD.3 Classify objects and count the number of objects in each category.

K.WEA Weather

Students who demonstrate understanding can:

a. **Carry out an investigation to determine the effect of sunlight on natural materials on Earth's surface.** [Clarification Statement: Examples of natural resources on the Earth's surface that can be investigated are rocks, water, soil, or sand.] [Assessment Boundary: Quantitative comparisons of data are limited to comparing numbers.]

b. **Observe, record, and share findings of local weather over a period of time.** [Clarification Statement: Students can observe local weather data such as sunlight, wind, snow, rain, and temperature over multiple time periods such as hourly, daily, weekly, and over the school year.] [Assessment Boundary: Climate is not assessed.]

c. **Develop, use, and share representations of weather conditions to describe changes over time and identify patterns.** [Assessment Boundary: Not to include histograms and line graphs.]

d. **Analyze weather data to determine that some kinds of severe weather are more likely to occur than others in the local region.** [Clarification Statement: Students can use weather data to compare likelihood of events such as rain vs. hurricane; typical temperature vs. heat wave; wind vs. tornado.] [Assessment Boundary: Limited to students' local region.]

e. **Ask questions and obtain information on how forecasting of severe weather can help keep people safe.** [Assessment Boundary: Students are not expected to make measurements of weather data or to forecast weather.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.
- Ask questions about observations of the natural world. (e)

Developing and Using Models
Modeling in K–2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions.
- Develop and use models (i.e., diagrams, drawings, physical replicas) that represent amounts, relative scales (bigger, smaller), and patterns. (c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
- Plan and carry out investigations collaboratively. (a)
- Evaluate different ways of observing and/or measuring an attribute of interest. (a)
- Make observations and/or measurements to collect data which can be used to make comparisons. (a)
- Identify questions and make predictions based on prior experiences. (a)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Use observations to note patterns in order to answer scientific questions and solve problems. (d)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the K–2 level builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world.
- Use data to identify patterns in the natural and designed worlds. (d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.
- Read and comprehend grade-appropriate texts and/or use other reliable media to acquire scientific information. (e)
- Critique and communicate information with others in oral and/or written forms using models, drawings, writing, or numbers. (b)
- Record observations, thoughts, and ideas. (b)

Disciplinary Core Ideas

PS3.B: Conservation of Energy and Energy Transfer
- Sunlight warms Earth's surface. (a)

ESS2.D: Weather and Climate
- Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (b),(c),(d)

ESS3.B: Natural Hazards
- Some kinds of severe weather are more likely than others in a given region. (d)
- Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. (d),(e)

ETS1.A: Defining and Delimiting an Engineering Problem
- Asking questions, making observations, and gathering information are helpful in thinking about problems. (e)

ETS2.B: Interactions of Engineering, Technology, Science, Society, and the Natural Environment
- People depend on various technologies in their lives; human life would be very different without technology. (e)

Crosscutting Concepts

Patterns
Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (b),(c)

Cause and Effect
Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes. (a)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. Therefore, taking natural materials to make things impacts the environment. (e)

Connections to other DCIs in this grade-level: **K.OTE**

Articulation of DCIs across grade-levels: **1.SF, 2.ECS, 3.WCI, 4.E**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.K.2 With prompting and support, identify the main topic and retell key details of a text.

W.K.2 Use a combination of drawing, dictating, and writing to compose informative/explanatory texts in which they name what they are writing about and supply some information about the topic.

SL.K.3 Ask and answer questions in order to seek help, get information, or clarify something that is not understood.

SL.K.5 Add drawings or other visual displays to descriptions as desired to provide additional detail.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.7 Look for and make use of structure.

K.MD.3 Classify objects and count the number of objects in each category.

1.SF Structure and Function

1.SF Structure and Function

Students who demonstrate understanding can:

a. **Observe and analyze the external structures of animals to explain how these structures help the animals meet their needs.** [Clarification Statement: External structures on animals allow them to gather, catch, eat, and chew food.]

b. **Make observations to explain that animals, including people, have body parts that they use to obtain and convey information, which the animal responds to with behaviors that help them grow and survive.** [Clarification Statement: Animals use body parts such as eyes, ears, nose, and skin to obtain information. Animals have developed behaviors such as the ability to find food or escape from a predator to respond to that information.]

c. **Make observations and describe that plants have different parts that help them survive, grow, produce more plants and respond to external inputs.** [Clarification Statement: Plants use different parts such as roots, stems, leaves, flowers, and fruits to help them survive, grow and produce more plants. Plants are also able to respond to external inputs such as leaves turning toward the sun to acquire more sunlight.]

d. **Ask questions to define a problem and design an object that replicates the function (use) of a structure (part) present in an animal or a plant to address the problem.** [Clarification Statement: Examples of a device could be a device to pick up small objects based on an animal structure such as a bird beak.]

e. **Gather and use data to explain that young animals and plants grow and change, and not all individuals of the same kind of organism look exactly the same.** [Clarification Statement: An example could be how puppies in the same litter look different.] [Assessment Boundary: Complete life cycles are not included.]

f. **Obtain and share information to explain that patterns of behaviors between parents and offspring promote survival.** [Clarification Statement: An example could be how adults feed their young.]

g. **Use observations and information as evidence that animals form groups of varying size and to describe how being part of a group can help individuals survive.** [Clarification Statement: Animals form groups of varying size such as pairs, family groups, and large herds to obtain food, defend themselves, and cope with change.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.
- Ask questions about observations of the natural and designed world. (d)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Use observations to note patterns and relationships in order to answer scientific questions and solve problems. (a),(c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.
- Use information from observations to construct explanations about investigations. (b),(e)
- Use tools and materials provided to design a solution to a specific problem. (d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.
- Read and comprehend grade-appropriate texts and use other reliable media to acquire scientific information. (f),(g)
- Record observations, thoughts, and ideas. (f)

Disciplinary Core Ideas

PS4.C: Information Technologies and Instrumentation
- People use their senses to learn about the world around them. Their eyes detect light, their ears detect sound, and they can feel vibrations by touch. (b)

LS1.A: Structure and Function
- All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. (a),(b),(d)
- Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive, grow, and produce more plants. (c)

LS1.B: Growth and Development of Organisms
- Plants and animals have predictable characteristics at different stages of development. Plants and animals grow and change. (e)
- Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive. (f)

LS1.D: Information Processing
- Animals have body parts that capture and convey different kinds of information needed for growth and survival—for example, eyes for light, ears for sounds, and skin for temperature or touch. Animals respond to these inputs with behaviors that help them survive (e.g., find food, run from a predator). Plants also respond to some external inputs (e.g., turn leaves toward the sun). (b),(c)

LS2.A: Interdependent Relationships in Ecosystems
- They [animals] use their senses to find food and water, and they use their body parts to gather, catch, eat, and chew the food. (a),(b)

LS2.D: Social Interactions and Group Behavior
- Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size. (g)

LS3.A: Inheritance of Traits
- Organisms have characteristics that can be similar or different. Young animals are very much, but not exactly, like their parents and also resemble one other animals of the same kind. Plants also are very much, but not exactly, like their parents and resemble other plants of the same kind. (e)

LS3.B: Variation of Traits
- Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways. (e)

ETS1.A: Defining and Delimiting an Engineering Problem
- Before beginning to design a solution, it is important to clearly understand the problem. (d)

Crosscutting Concepts

Patterns
Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (e),(f),(g)

Structure and Function
The shape and stability of structures of natural and designed objects are related to their function(s). (a),(b),(c)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. Therefore, taking natural materials to make things impacts the environment. (d)

Connections to other DCIs in this grade-level: **1.LS**

Articulation of DCIs across grade-levels: **K.WEA, 2.PP, 2.IOS, 3.SFS, 3.EIO, 4.LCT, 4.WAV**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.1.2 Identify the main topic and retell key details of a text.
RI.1.10 With prompting and support, read informational texts appropriately complex for grade.
W.1.2 Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.
MP.3 Construct viable arguments and critique the reasoning of others.
MP.7 Look for and make use of structure.
1.G.2 Reason with shapes and their attributes.

1.LS Light and Sound

1.LS Light and Sound

Students who demonstrate understanding can:

a. **Investigate to describe that objects can be seen only when light is available to illuminate them.**

b. **Obtain and communicate information that very hot objects give off their own light.** [Assessment boundary: Examples of very hot objects that give off their own light are fire and the sun.]

c. **Investigate that some materials allow light to pass through, others only allow some light to pass through, and some materials block all of the light, creating a dark shadow.**

d. **Investigate to describe how mirrors and prisms redirect light.** [Assessment Boundary: Only descriptions from the observations of the phenomenon of light being redirected from a mirror and a prism to be included.]

e. **Carry out investigations to provide evidence that vibrating matter creates sound and that sound can cause matter to vibrate.** [Clarification Statement: Examples of vibrating matter that creates sound could be tuning forks or plucking a stretched string. An example of how sound can cause matter to vibrate could be holding a piece of paper near a speaker.]

f. **Design a device that uses light or sound to send a signal over a distance.** [Clarification Statement: Examples of devices could include a light source to send signals, paper cup and string "telephones," or drum beats.]

g. **Provide evidence that communicating over distances is important in our daily lives.** [Assessment Boundary: Technological details for how communication devices work should not be included.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Plan and carry out investigations collaboratively. (a),(c),(d),(e)
- Evaluate different ways of observing an attribute of interest. (a),(c),(d),(e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.

- Use tools and materials provided to design a solution to a specific problem. (f)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Read and comprehend grade-appropriate texts and use other reliable media to acquire scientific information. (b),(g)
- Record observations, thoughts, and ideas. (b),(g)

Disciplinary Core Ideas

PS4.A: Wave Properties

- Sound can make matter vibrate, and vibrating matter can make sound. (e)

PS4.B: Electromagnetic Radiation

- Objects can be seen only when light is available to illuminate them. Very hot objects give off light (e.g., a fire, the sun). (a),(b)
- Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them (i.e., on the other side from the light source), where the light cannot reach. (c)
- Mirrors and prisms can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) (d)

PS4.C: Information Technologies and Instrumentation

- People also use a variety of devices to communicate (send and receive information) over long distances. (f)

ETS2.B: Interactions of Engineering, Technology, Science, on Society and the Natural Environment

- People depend on various technologies in their lives; human life would be very different without technology. (g)

Crosscutting Concepts

Cause and Effect

Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes. (a),(b),(c),(d),(e)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science, on Society and the Natural World

Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. Therefore, taking natural materials to make things impacts the environment. (f)

Connections to other DCIs in this grade-level: **1.SF**

Articulation of DCIs across grade-levels: **2.ECS, 3.SFS, 4.WAV**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.1.2 Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure.

SL.1.1 Participate in collaborative conversations with diverse partners about grade 1 topics and texts with peers and adults in small and larger groups.

SL.1.5 Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.

MP.3 Construct viable arguments and critique the reasoning of others.

1.MD.3 Measure lengths indirectly and by iterating length units.

1.PC Patterns and Cycles

1.PC Patterns and Cycles

Students who demonstrate understanding can:

a. Investigate and compare how some natural events occur quickly and other natural events occur slowly. [Clarification Statement: Quickly occurring natural events could include rain storms or gusts of wind. Slower events could be the change of seasons.]

b. Record and share observations about how some events have cycles; whereas, other events have a clear beginning and end. [Clarification Statement: Observations can be made about cycles such as day and night while using storms as examples of events that begin and end.]

c. Obtain information and share observations to determine simple patterns of natural objects in the sky. [Clarification Statement: Examples of patterns could be that the sun rises in one part of the sky and sets in another or that stars are visible at night.]

d. Analyze and share observations about sunrise and sunset to identify and describe seasonal changes.

e. Obtain information and communicate that there are tools that allow people to see more objects in the sky and in greater detail. [Clarification Statement: Information can be obtained using telescopes, binoculars, or reliable media. For example, as a result of these tools, we can see more stars and study the moon in greater detail.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
- Make observations and/or measurements to collect data which can be used to make comparisons. (a)
- Identify questions and make predictions based on prior experiences. (a)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Use and share pictures, drawings, and/or writings of observations where appropriate. (b),(c),(d)
- Use observations to note patterns and relationships in order to answer scientific questions. (b),(d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.
- Read and comprehend grade-appropriate texts and/or use other reliable media to acquire scientific and technical information. (c),(e)
- Critique and communicate information or design ideas with others in oral and/or written forms using models, drawings, writing, or numbers. (c)

Disciplinary Core Ideas

ESS1.A: The Universe and its Stars
- Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (c),(d)
- At night one can see the light coming from many stars with the naked eye, but telescopes make it possible to see many more and to observe them and the moon and planets in greater detail. (e)

ESS1.B: Earth and the Solar System
- Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (c),(d)

ESS1.C: The History of Planet Earth
- Some events on Earth occur in cycles, like day and night, and others have a beginning and an end, like a volcanic eruption. (b)
- Some events, like an earthquake, happen very quickly; others, such as the formation of the Grand Canyon, occur very slowly, over a time period much longer than one can observe. (a)

Crosscutting Concepts

Patterns
Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (b),(c),(d)

Stability and Change
Some things stay the same while other things change. Things may change slowly or rapidly. (a)

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Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
Science and engineering involve the use of tools to observe and measure things. (e)

Connections to other DCIs in this grade-level: **N/A**

Articulation of DCIs across grade-levels: **4.PSE, 5.SSS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.1.2 Identify the main topic and retell key details of a text.
RI.1.10 With prompting and support, read informational texts appropriately complex for grade
W.1.2 Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure.
SL.1.5 Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.7 Look for and make use of structure.
1.MD.3 Tell and write time.

2.ECS Earth's Changing Surface

2.ECS Earth's Changing Surface

Students who demonstrate understanding can:

a. **Obtain and communicate information that water exists in different forms within natural landscapes and determines the variety of life forms that can live there.** [Clarification Statement: Students should gather information on oceans, rivers, lakes, ponds and moisture in the soil.]
b. **Investigate how wind and water can move Earth materials from one place to another and change the shape of landforms.** [Clarification Statement: Examples of changing shapes of landforms could be sediments build up at the mouth of the river, building and rebuilding of sand dunes.]
c. **Design, test, and refine a technological solution that would prevent changes to land caused by wind or water and communicate the solution using sketches, drawings, or physical models.**
d. **Obtain and share information about how landforms provide homes for living things.** [Clarification Statement: Examples of landforms that provide homes are caves used as shelters, marshes used for nesting grounds.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in K–2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions.

- Distinguish between a model and the actual object, process, and events the model represents. (c)
- Compare models to identify common features and differences. (c)
- Develop and use models (i.e., diagrams, drawings, or physical replicas) that represent amounts, relative scales (bigger, smaller) and patterns. (c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Plan and carry out investigations collaboratively. (b)
- Identify questions and make predictions based on prior experiences. (b)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Read and comprehend grade-appropriate texts and use other reliable media to acquire scientific. (a),(d)
- Critique and communicate information or design ideas with others in oral and written forms using models and drawings. (c)
- Record observations, thoughts, and ideas. (a),(d)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems

- Wind and water can change the shape of the land. The resulting landforms, together with the materials on the land, provide homes for living things. (b),(c),(d)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. It carries soil and rocks from one place to another and determines the variety of life forms that can live in a particular location. (a),(b)

ETS1.B: Developing Possible Solutions

- Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (c)

ETS1.C: Optimizing the Design Solution

- Because there is always more than one possible solution to a problem, it is useful to compare designs, test them, and discuss their strengths and weaknesses. (c)

ETS2.A: Interdependence of Science, Engineering, and Technology

- Observations and measurements are also used in engineering to help test and refine design ideas. (c)

ETS2.B: Interactions of Engineering, Technology, Science, Society, and the Natural Environment

- Developing and using technology has impacts on the natural world. (c)

Crosscutting Concepts

Cause and Effect
Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes. (a),(b)

Systems and System Models
Objects and organisms can be described in terms of their parts. Systems in the natural and designed world have parts that work together. (d)

Connections to other DCIs in this grade-level: **2.IOS, 2.SPM**

Articulation of DCIs across grade-levels: **1.LS, 3.WCI, 3.IF, 4.PSE, 4.E**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.2.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 2–3 text complexity band proficiently, with scaffolding as needed at the high end of the range.
W.2.2 Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section.
W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations).
SL.2.1 Participate in collaborative conversations with diverse partners about grade 2 topics and texts with peers and adults in small and larger groups.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.
MP.7 Look for and make use of structure.
2.MD.1 Measure and estimate lengths in standard units.

2.SPM Structure, Properties, and Interactions of Matter

2.SPM Structure, Properties, and Interactions of Matter

Students who demonstrate understanding can:

a. **Evaluate natural or designed objects to explain how the properties of the materials suit different purposes.** [Clarification Statement: Examples of materials could be hard turtle shell for protection, soft pillows for comfort.]

b. **Collaborate with others to design an object built from a small set of pieces to solve a technological problem.** [Clarification Statement: Examples of technological problems could be transporting or supporting an object with blocks or construction sets.]

c. **Provide evidence that some changes caused by heating or cooling can be reversed and some cannot.** [Clarification Statement: Examples of reversible changes could be melting chocolate or freezing liquids. Irreversible changes could be cooking food.]

d. **Measure and compare the physical properties of objects.** [Clarification Statement: Students will measure and compare weight and size of objects.] [Assessment Boundary: Mass and weight are not distinguished at this grade level.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Make measurements of length using standard units to quantify data. (d)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the K–2 level builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world.
- Use standard units to measure and compare the lengths of different objects and display the data using simple graphs. (d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.
- Use information from observations to construct explanations about investigations. (a)
- Use tools and materials provided to design a solution to a specific problem. (b)

Engaging in Argument from Evidence
Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world.
- Distinguish arguments that are supported by evidence from those that are not. (c)
- Listen actively to others' arguments and ask questions for clarification. (c)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Different properties are suited to different purposes. (a)
- A great variety of objects can be built up from a small set of pieces (e.g., blocks, construction sets). (b)
- Objects or samples of a substance can be weighed, and their size can be described and measured. (Boundary: volume is introduced only for liquid measure.) (d)

PS1.B: Chemical Reactions
- Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible (e.g., melting and freezing), and sometimes they are not (e.g., baking a cake, burning fuel). (c)

ETS2.A: Interdependence of Science, Engineering, and Technology
- There are many types of tools produced by engineering that can be used in science to help answer these questions through observation and measurement. (d)

Crosscutting Concepts

Scale, Proportion, and Quantity
Relative scales allow objects to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). Standard units are used to measure length. (a),(c),(d)

Energy and Matter
Objects may break into smaller pieces and be put together into larger pieces, or change shapes. (b)

- -

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science, on Society and the Natural World
Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. Therefore, taking natural materials to make things impacts the environment. (b)

Connections to other DCIs in this grade-level: **2.PP, 2.ECS**

Articulation of DCIs across grade-levels: **K.SPM, 5.SPM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.2.2 Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section.

W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations).

SL.2.3 Ask and answer questions about what a speaker says in order to clarify comprehension, gather additional information, or deepen understanding of a topic or issue.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.3 Construct viable arguments and critique the reasoning of others.

2.MD.1,4 Measure and estimate lengths in standard units.

2.MD.9,10 Represent and interpret data.

2.IOS Interdependence of Organisms and Their Surroundings

2.IOS Interdependence of Organisms and Their Surroundings

Students who demonstrate understanding can:

a. **Construct a representation in which plants and animals depend on their environment and each other to meet their needs.** [Assessment Boundary: Needs to be limited to food, water, shelter, and a favorable temperature for animals; light, water, and soil for plants.]

b. **Ask questions to clarify ideas about how plants may depend on animals for pollination or to move their seeds around.**

c. **Plan and carry out investigations to test whether plants from different settings have different needs for water, sunlight, and type of soil.** [Clarification Statement: Examples of different settings could be a sunny vs. shady area or a garden vs. a parking lot.]

d. **Observe and compare the many kinds of living things that are found in different areas.** [Clarification Statement: Examples of different areas could be salt vs. fresh water or desert vs. woodland.]

e. **Analyze a representation of a particular habitat showing the locations and shapes of both land and water features of that habitat and communicate how the land and water support animals and plants.** [Clarification Statement: Examples could include plants and animals in the school yard, a park, a pond, a terrarium, or an aquarium.]

f. **Construct an explanation about the effect of environmental changes – whether slow or rapid – on the survival of plants and animals that live there.** [Clarification Statement: Examples of slow or rapid environmental changes could be droughts or floods.]

g. **Obtain and communicate information that some kinds of animals and plants that once lived on Earth are no longer found anywhere, although others living now may resemble them.** [Clarification Statement: Examples elephants which resemble mammoths or tigers which resemble saber-tooth cats.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.

- Ask questions about observations of the natural world. (b)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Plan and carry out investigations collaboratively. (c)
- Make observations and measurements to collect data which can be used to make comparisons. (c)
- Identify questions and make predictions based on prior experiences. (c)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

- Use and share pictures, drawings, and writings of observation where appropriate. (d),(e)
- Use observations to note patterns and relationships in order to answer scientific questions. (d)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the K–2 level builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world.

- Decide when to use qualitative vs. quantitative data. (c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.

- Use information from observations to construct explanations about investigations. (f)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Read and comprehend grade-appropriate texts and use other reliable media to acquire scientific information. (g)
- Critique and communicate information with others in oral and written forms using models or drawings. (a)
- Record observations, thoughts, and ideas. (g)

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

- Animals depend on their surroundings to get what they need, including food, water, shelter, and a favorable temperature. Animals depend on plants or other animals for food. (a)
- Plants depend on air, water, minerals (in the soil), and light to grow. (b)
- Animals can move around, but plants cannot, and they often depend on animals for pollination or to move their seeds around. (b)
- Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight. (c)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

- Organisms obtain the materials they need to grow and survive from the environment. Many of these materials come from organisms, and are used again by other organisms. (a)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- The places where plants and animals live often change, sometimes slowly and sometimes rapidly. (f)
- When animals and plants get too hot or too cold, they may die. If they cannot find enough food, water, or air, they may die. (f)

LS4.A: Evidence of Common Ancestry and Diversity

- Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways. (g)

LS4.C: Adaptation

- Living things can survive only where their needs are met. If some places are too hot or too cold or have too little water or food, plants and animals may not be able to live there. (f)

LS4.D: Biodiversity and Humans

- There are many different kinds of living things in any area, and they exist in different places on land and in water. (d)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- Rocks, soils, and sand are present in most areas where plants and animals live. There may also be rivers, streams, lakes, and ponds. Maps show where things are located. One can map the shapes and kinds of land and water in any area. (e)

Crosscutting Concepts

Scale, Proportion, and Quantity
Relative scales allow objects to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). Standard units are used to measure length. (c),(d),(e)

Stability and Change
Some things stay the same while other things change. Things may change slowly or rapidly. (f),(g)

Connections to other DCIs in this grade-level: **2.ECS**

Articulation of DCIs across grade-levels: **1.SF, 3.EIO, 4.PSE, 5.MEE**

Common Core State Standards Connections:[Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.2.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 2–3 text complexity band proficiently, with scaffolding as needed at the high end of the range.

W.2.2 Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section.

SL.2.1 Participate in collaborative conversations with diverse partners about grade 2 topics and texts with peers and adults in small and larger groups.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.3 Construct viable arguments and critique the reasoning of others.

2.MD.1,4 Measure and estimate lengths in standard units.

2.MD.10 Represent and interpret data.

2.PP Pushes and Pulls

2.PP Pushes and Pulls

Students who demonstrate understanding can:

a. Investigate the effect of pushes and pulls in different directions on the resulting motion of objects. [Assessment Boundary: Simultaneous pushes and pulls to be along a single line; pushes and pulls to be between objects in contact. Students not to be assessed on quantitative relationships.]

b. Investigate the effect of pushes and pulls of different strengths on the resulting motion of objects. [Assessment Boundary: Simultaneous pushes and pulls to be along a single line; pushes and pulls to be between objects in contact. Students not to be assessed on quantitative relationships.]

c. Construct an explanation for why an object subjected to multiple pushes and pulls might stay in one place or move. [Assessment Boundary: Pushes and pulls should be between objects in contact]

d. Analyze data to determine the relationship between friction and the motion of objects. [Clarification Statement: The data analyzed should be focused on observations on the interaction between objects and the type or slope of the surface. For example, an object sliding on rough vs. smooth surfaces on a slope.]

e. Analyze data to determine the relationship between friction and the warming of objects. [Clarification Statement: Data should be observations that allow students to compare the effects of rubbing two objects together.] [Assessment Boundary: Observation of warming is qualitative.]

f. Develop and share a design solution to reduce friction between two objects. [Clarification Statement: Examples of ways to reduce friction include putting lubricant on a surface to make objects slide more easily.]

g. Plan and carry out investigations of how the change in motion and/or shape when objects touch or collide is related to the speed of the objects. [Clarification Statement: Examples of investigations could include a ball of clay thrown against a wall at different speeds.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Plan and carry out investigations collaboratively. (g)
- Evaluate different ways of observing an attribute of interest. (g)
- Make observations to collect data which can be used to make comparisons. (a),(b),(g)
- Identify questions and make predictions based on prior experiences. (a),(b)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

- Use and share pictures, drawings, and writings of observation where appropriate. (d),(e)
- Use observations to note relationships in order to answer scientific questions and solve problems. (d),(e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions.

- Use information from observations to construct explanations about investigations. (c),(f)
- Use tools and materials provided to design a solution to a specific problem. (f)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Objects pull or push each other when they collide or are connected. Pushes and pulls can have different strengths and directions. (a),(b)
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (a),(b),(g)
- An object sliding on a surface or sitting on a slope experiences a pull due to friction on the object due to the surface that opposes the object's motion. (d)

PS2.B: Types of Interactions

- When objects touch or collide, they push on one another and can change motion or shape. (g)

PS2.C: Stability and Instability in Physical Systems

- Whether an object stays still or moves often depends on the effects of multiple pushes and pulls on it (e.g., multiple players trying to pull an object in different directions). It is useful to investigate what pushes and pulls keep something in place (e.g., a ball on a slope, a ladder leaning on a wall) as well as what makes something change or move. (c)

PS3.C: Relationship Between Energy and Forces

- A bigger push or pull makes things go faster. Faster speeds during a collision can cause a bigger change in shape of the colliding objects. (b),(g)

PS3.D: Energy in Chemical Processes and Everyday Life

- When two objects rub against each other this interaction is called friction. Friction between two surfaces can warm both of them (e.g., rubbing hands together). There are ways to reduce the friction between two objects. (d),(e),(f)

ETS1.A: Defining Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (f)

Crosscutting Concepts

Cause and Effect
Events have causes that generate observable patterns. Simple tests can be designed to gather evidence to support or refute student ideas about causes. (a),(b),(d),(e),(g)

Stability and Change
Some things stay the same while other things change. Things may change slowly or rapidly. (c)

- -

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. Therefore, taking natural materials to make things impacts the environment. (f)

Connections to other DCIs in this grade-level: **2.SPM**

Articulation of DCIs across grade-levels: **1.SF, 3.IF, 4.E**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.2.2 Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section.

W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations).

SL.2.1 Participate in collaborative conversations with diverse partners about grade 2 topics and texts with peers and adults in small and larger groups.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.

MP.3 Construct viable arguments and critique the reasoning of others.

2.MD.10 Represent and interpret data.

3.WCI Weather, Climate, and Impacts

3.WCI Weather, Climate, and Impacts

Students who demonstrate understanding can:

- **a. Use mathematics and computational thinking to observe and record local weather data over time using standard units.** [Clarification Statement: Examples of weather data could include temperature, precipitation, wind speed, or wind direction. Students should use standards units such as degrees and centimeters per year.]
- **b. Analyze and interpret weather data to identify day-to-day variations as well as long-term patterns.** [Clarification Statement: Examples of weather data could include maps and forecasts. Students should address climate in terms of long term patterns.]
- **c. Obtain information about different climatic areas to predict typical weather conditions expected in a particular season in a given area.** [Clarification Statement: Examples of climatic areas could include tropical, dry, temperate/moderate, tundra, cold, or polar. The focus is not on addressing each of the areas, rather students should be able to predict typical conditions based on a set of information.]
- **d. Obtain and evaluate information about a variety of weather-related hazards that result from natural processes, as well as their environmental and societal impacts.** [Clarification Statement: Examples of natural processes could include severe weather, floods, or coastal erosion.] [Assessment Boundary: Natural hazards limited to weather-related hazards.]
- **e. Collaboratively design, compare, and refine solutions that reduce the environmental or societal impact of a weather-related hazard.** [Clarification Statement: Examples of solutions to weather-related hazards could be physical models of barriers to prevent flooding or physical models of buildings that withstand high winds.] [Assessment Boundary: Natural hazards limited to weather-related hazards.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and multiple trials of qualitative observations.
- Compare data collected by different groups in order to discuss similarities and differences in their findings. (b)
- Use data to evaluate and refine design solutions. (e)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 3–5 level builds on K–2 and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.
- Use mathematical thinking to compare alternative solutions to an engineering problem. (e)
- Analyze simple data sets for patterns that suggest relationships. (b)
- Use standard units to measure area, volume, weight, and temperature. (a)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and synthesize across texts and other reliable media to acquire generate appropriate scientific information. (c)
- Synthesize information in written text with that contained in corresponding tables, diagrams, and charts. (c),(d)
- Generate and communicate scientific information orally and in written formats using various forms of media, and may include tables, diagrams, and charts. (c)
- Use models to share findings or solutions in oral or written presentations, or extended discussions. (d)

Disciplinary Core Ideas

ESS2.D: Weather and Climate
- Weather is the minute-by-minute to day-by-day variation of the atmosphere's condition on a local scale. Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years to centuries. (a),(b),(c)

ESS3.B: Natural Hazards
- A variety of natural hazards result from natural processes (e.g. severe weather, floods, and coastal erosion). Humans can not eliminate natural hazards but can take steps to reduce their impacts. (d)

ETS2.B: Interactions of Engineering, Technology, Science, Society, and the Natural Environment
- When new technologies become available, they can bring about changes in the way people live and interact with one another. (e)

Crosscutting Concepts

Patterns
Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. Cyclic patterns of change related to time can be used to make predictions. (b),(c)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
Science and technology support each other. Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies. (a)

Influence of Engineering, Technology, and Science on Society and the Natural World
People's needs and wants change over time, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. When new technologies become available, they can bring about changes in the way people live and interact with one another. (d),(e)

Connections to other DCIs in this grade-level: **N/A**

Articulation of DCIs across grade-levels: **K.WEA, 2.ECS, 4.LCT, MS.ESS-WC**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

Consider adding RI.3,4,5,8

RI.3.3 Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect.
RI.3.9 Compare and contrast the most important points and key details presented in two texts on the same topic.
RI.3.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text
SL.3.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.
MP.7 Look for and make use of structure.
3.MD.1,2 Solve problems involving measurement and estimation of intervals of time, liquid volumes, and masses of objects.
3.MD.3 Represent and interpret data.

3.EIO Environmental Impacts on Organisms

3.EIO Environmental Impacts on Organisms

Students who demonstrate understanding can:

a. **Obtain, evaluate, and communicate information about the types of habitats in which organisms live, and ask questions based on that information.** [Clarification Statement: Examples of habitats could be ponds, woods, grasslands, or deserts. Questions could include how changes in habitats affect the organisms living there.]

b. **Obtain, evaluate, and communicate information that in any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.** [Clarification Statement: An example could be that plants that require a lot of water would not survive well in a desert.]

c. **Analyze data to describe how humans, like all other organisms, obtain living and non-living resources from their environment.** [Clarification Statement: Examples of living and non-living resources could include minerals, food, and energy.]

d. **Use models to evaluate how environmental changes in a habitat affect the number and types of organisms that live there; some remain, move in, move out, and/or die.** [Clarification Statement: Examples of environmental changes could be extra water in a normally dry area, pollution, or fire. An example of how environmental changes can affect organisms could be the effects of a decrease in grass on a rabbit population.]

e. **Use evidence to argue that some changes in an organism's habitat can be beneficial or harmful to the organism.**

f. **Obtain and communicate information about the characteristics of groups of organisms and evaluate how groups help organisms survive.** [Clarification Statement: The characteristics of groups of organisms students should address are composition, organization, specialization, and stability. Examples of how groups help organisms survive could be worker bees supplying food and queens reproducing, female lions in a pride hunting and males patrolling the territory, or human families caring for children.] [Assessment Boundary: Detailed structure of social insect societies not to be included.]

g. **Use data about the characteristics of organisms and habitats to design an artificial habitat in which the organisms can survive.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.
- Ask questions based on careful observations of phenomena and information. (a)

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a natural or designed system. (d)

Analyzing and Interpreting Data
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Display data in tables and graphs, using digital tools when feasible, to reveal patterns that indicate relationships (c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or solution to a problem. (g)
- Apply scientific knowledge to solve design problems. (g)

Engaging in Written and Oral Argument from Evidence
Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world.
- Construct and/or support scientific arguments drawing on evidence, data, or a model. (e)
- Compare and refine multiple arguments based on the strengths and weaknesses of the evidence supporting the argument. (e)
- Respectfully provide and receive critique on the scientific arguments proposed by peers by citing relevant evidence and making logical arguments. (e)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and synthesize across texts and other reliable media to acquire and generate appropriate scientific information. (a),(b),(f)
- Generate and communicate scientific information orally and in written formats using various forms of media, and may include tables, diagrams, and charts. (a),(f)
- Use models to share findings or solutions in oral presentations, written presentations, and extended discussions and evaluate the merit and accuracy of ideas and methods. (d)

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (b),(g)

LS2.D: Social Interactions and Group Behavior
- Groups can be collections of equal individuals, hierarchies with dominant members, small families, groups of single or mixed gender, or groups composed of individuals similar in age. Some groups are stable over long periods of time; others are fluid, with members moving in and out. Some groups assign specialized tasks to each member; in others, all members perform the same or a similar range of functions. (e),(f)

LS4.C: Adaptation
- Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful. For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. (b),(d),(e),(g)

LS4.D: Biodiversity and Humans
- Populations of organisms live in a variety of habitats, and change in those habitats affects the organisms living there. (a),(b)
- Humans, like all other organisms, obtain living and nonliving resources from their environments. (c)

Crosscutting Concepts

Cause and Effect
Cause and effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause and effect relationship. (d),(f)

Systems and System Models
A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. A system can be described in terms of its components and their interactions. (a),(b),(c),(e)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Over time, people's needs and wants change, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. When new technologies become available, they can bring about changes in the way people live and interact with one another. (g)

3.EIO Environmental Impacts on Organisms

3.EIO Environmental Impacts on Organisms *(continued)*

Connections to other DCIs in this grade-level: **3.SFS**

Articulation of DCIs across grade-levels: **1.SF, 2.IOS, MS.LS-NSA, MS.LS-IRE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.3.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text complexity band independently and proficiently.

W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

SL.3.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly.

SL.3.4 Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.3 Construct viable arguments and critique the reasoning of others.

3.MD.3 Represent and interpret data.

3.SFS Structure, Function, and Stimuli

3.SFS Structure, Function, and Stimuli

Students who demonstrate understanding can:

a. Investigate and explain how internal and external structures in plants serve functions of growth, survival, behavior, and reproduction. [Clarification Statement: Examples of internal and external structures could include roots, thorns, or veins in leaves.] [Assessment Boundary: Emphasis on understanding the macroscale systems and their function, not microscopic processes.]

b. Construct explanations of how structures in animals serve functions of growth, survival, reproduction, and behavior. [Clarification Statement: Examples of internal and external structures could include heart, teeth, bones, brains, muscles, or skin.] [Assessment Boundary: Emphasis on understanding the macroscale systems and their function, not microscopic processes.]

c. Design a device that replaces an external structure and analyze data on its physical properties to compare alternative solutions to the problem. [Clarification Statement: Examples could include designing crutches or prostheses to replace a leg and testing the strength of different models or designing a grabber to replace a hand and testing its effectiveness.]

d. Use observations and models to design a simple process to classify plants and animals based on their structures. [Clarification Statement: Examples of categories of classification could be plants that make flowers, plants that make cones, and plants that make neither; vertebrates have backbones, mammals have hair, insects have six legs, or birds have feathers.] [Assessment Boundary: Students need to know that plants and animals can be classified but not use a classification chart.]

e. Obtain information that animals have structures that allow them to respond to stimuli through instinct or memory. [Clarification Statement: Examples of structures could be eyes, ears, or brain. Examples of responding to stimuli could be running from danger or learning the alphabet.]

f. Investigate and explain that for an object to be seen, light must be reflected off the object and enter the eye. [Clarification Statement: Examples of investigations could include students using mirrors to reflect light into the eye.] [Assessment Boundary: Emphasis on understanding the phenomenon that light traveling from the object to the eye determines what is seen.]

g. Investigate and provide evidence that the color people see depends on the color of the available light sources as well as the properties of the surface of the object reflecting the light. [Clarification Statement: Examples of investigations could be illuminating objects with different colors of light or illuminating objects that have different surfaces.] [Assessment Boundary: This phenomenon is observed, but no attempt is made to discuss what confers the color reflection and absorption properties on a surface.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in K–2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions.
- Use simple models to describe phenomena concerning the functioning of a natural or designed system. (d)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Make observations, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon or test a design solution. (a),(d),(f),(g)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 3–5 level builds on K–2 and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.
- Use mathematical thinking and computational outcomes to compare alternative solutions to an engineering problem. (c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or solution to a problem. (b),(c),(d)
- Apply scientific knowledge to solve design problems. (c),(d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and synthesize across texts and other reliable media to acquire appropriate scientific information. (e)

Disciplinary Core Ideas

PS4.B: Electromagnetic Radiation
- An object can be seen when light reflected from its surface enters the eyes; the color people see depends on the color of the available light sources as well as the properties of the surface. (f),(g)

LS1.A: Structure and Function
- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (a),(b),(c)

LS1.D: Information Processing
- Different sense receptors are specialized for particular kinds of information, which may be then processed and integrated by the animal's brain, with some information stored as memories. Animals are able to use their perceptions and memories to guide their actions. Some responses to information are instinctive—that is, animals' brains are organized so that they do not have to think about how to respond to certain stimuli. (e)

LS4.D: Biodiversity and Humans
- Scientists have identified and classified many plants and animals. (d)

Crosscutting Concepts

Cause and Effect
Cause and effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause and effect relationship. (f),(g)

Structure and Function
Different materials have different substructures, which can sometimes be observed. Substructures have shapes and parts that serve functions. (a),(b),(e)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
People's needs and wants change over time, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. When new technologies become available, they can bring about changes in the way people live and interact with one another. (c),(d)

Connections to other DCIs in this grade-level: **3.EIO**

Articulation of DCIs across grade-levels: **1.LS, 1.SF, 5.SSS, MS.LS-SFIP, MS.LS-IRE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.3.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text complexity band independently and proficiently.

W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

SL.3.4 Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.

MP.3 Construct viable arguments and critique the reasoning of others.

MP.7 Look for and make use of structure.

3.MD.1,2 Solve problems involving measurement and estimation of intervals of time, liquid volumes, and masses of objects.

3.MD.3 Represent and interpret data.

3.IF Interactions of Forces

3.IF Interactions of Forces

Students who demonstrate understanding can:

a. Investigate the motion of objects to determine observable and measurable patterns to predict future motions. [Clarification Statement: Examples of motions are a ball rolling down a slide or a child swinging in a swing.] [Assessment Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity are not introduced.]

b. Investigate the motion of objects by comparing the relative sizes and direction of forces on an object at rest to the forces on an object whose motion is changing. [Clarification Statement: Examples investigations could include pulling a wagon or pushing on a heavy object that will not slide.] [Assessment Boundary: Dependence on variables of motion is to be tested one variable at a time. The size and direction of forces should be qualitative. Gravity only to be addressed as a force that pulls objects down.]

c. Use models to explain the effects of balanced and unbalanced forces on a system.

d. Investigate the forces between two or more magnets to identify patterns. [Clarification Statement: Examples of patterns could include strength of attraction and distance, attracting or repelling based on orientation.]

e. Investigate the push-and-pull forces between objects not in contact with one another. [Clarification Statement: Examples of objects could be force on hair from an electrically charged balloon or the force between two magnets.] [Assessment Boundary: Energy and gravity are not to be assessed. Assessment is limited to forces produced by objects that can be manipulated and observed by students.]

f. Design and refine solutions to a problem by using magnets to move objects not in contact with one another. [Clarification Statement: Examples of solutions could be to move a metal object through a maze or build a model of a maglev train.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Construct a model using an analogy, example, or abstract representation to explain a scientific principle or design solution. (c)
- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a natural or designed system. (c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (e)
- Make observations, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon. (b),(d)
- Formulate questions and predict reasonable outcomes based on patterns such as cause and effect relationships. (a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Apply scientific knowledge to solve design problems. (f)

Disciplinary Core Ideas

PS2.A: Forces and Motion
- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (b),(c)
- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (a)

PS2.B: Types of Interactions
- Objects in contact exert forces on each other (friction, elastic pushes and pulls). Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact—for example, magnets push or pull at a distance. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (d),(e),(f)

PS2.C: Stability and Instability in Physical Systems
- A system can change as it moves in one direction (e.g., a ball rolling down a hill), shift back and forth (e.g., a swinging pendulum), or go through cyclical patterns (e.g., day and night). (a)
- Examining how the forces on and within the system change as it moves can help explain a system's patterns of change. (b)
- A system can appear to be unchanging when processes within the system are going on at opposite but equal rates (e.g., water behind a dam is at a constant height because water is flowing in at the same rate that water is flowing out). (c)
- Changes can happen very quickly or very slowly and are sometimes hard to see (e.g., plant growth). Conditions and properties of the objects within a system affect how fast or slowly a process occurs (e.g., heat conduction rates). (c)

ETS2.A: Interdependence of Science, Engineering, and Technology
- Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process. (f)

Crosscutting Concepts

Patterns
Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. Cyclic patterns of change related to time can be used to make predictions. (a),(d),(e)

Systems and System Models
A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. A system can be described in terms of its components and their interactions. (c)

Stability and Change
Change is measured in terms of differences over time and may occur at different rates. Some systems appear stable, but over long periods of time will eventually change. (b)

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Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
Science and technology support each other. Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies. (f)

Connections to other DCIs in this grade-level: **N/A**

Articulation of DCIs across grade-levels: **1.LS, 2.PP, 2.ECS, 4.WAV, 5.SSS, MS.PS-FM, MS.PS-IF**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.3.3 Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect.

SL.3.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly.

SL.3.3 Ask and answer questions about information from a speaker, offering appropriate elaboration and detail.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.

MP.2 Reason abstractly and quantitatively.

MP.3 Construct viable arguments and critique the reasoning of others.

3.MD.1 Solve problems involving measurement and estimation of intervals of time.

4.LCT Life Cycles and Traits

4.LCT Life Cycles and Traits

Students who demonstrate understanding can:

a. **Investigate the life cycles of plants and animals to compare similarities and differences among organisms.** [Clarification Statement: Examples of organisms to compare could be flowering plants, butterflies, and frogs.] [Assessment Boundary: Reproduction is addressed as part of the process – birth, growth, development, reproduction, death – and the different ways organisms go through the process.]

b. **Use evidence to compare characteristics inherited from parents, characteristics caused by the environment, and those resulting from both.** [Clarification Statement: Examples of characteristics inherited from parents could be the ability to roll one's tongue or characteristics of domestic animals; characteristics caused by the environment could be a scar or language; and characteristics resulting from both could be height or some health conditions.] [Assessment Boundary: The mechanisms of inheritance are not to be included.]

c. **Provide evidence that offspring can inherit different information from their parents.** [Clarification Statement: Examples of different information that can be inherited could be different coat colors in dogs of the same litter or one sibling who needs glasses and another who does not.] [Assessment Boundary: The genetic mechanisms of inheritance are not to be included.]

d. **Obtain and communicate information about different versions of the same traits in different kinds of organisms.** [Clarification Statement: Examples of different kinds of animals having different versions of the same trait could include the different lengths, textures, and colors of feathers, hair, or fur of different animals.] [Assessment Boundary: The genetic mechanisms of inheritance are not to be included.]

e. **Use evidence to describe patterns of variation in a trait across individuals of the same kind of organism.** [Clarification Statement: Examples of variation in a trait across individuals of the same kind of organism could be different coloration of wolves or thickness of wool in sheep.] [Assessment Boundary: The genetic mechanisms of inheritance are not to be included.]

f. **Use evidence to explain how some characteristics that vary among individuals of the same kind of organism can provide advantages to survive, find mates, and reproduce.** [Clarification Statement: Examples of advantages could include animals that run faster are better able to escape predators or birds with brighter colored feathers are more likely to attract mates.]

g. **Obtain information to explain how breeders use variations in traits to produce desired types of domesticated organisms.** [Clarification Statement: Examples could be sheep that are bred for thicker wool coats or disease resistant corn that is used in cultivation.]

h. **Obtain and communicate information that some characteristics of organisms have been used to inspire technology that meets societal needs.** [Clarification Statement: Students could identify technologies that utilize advantageous characteristics of organisms such as: sonar, insulated vests, camouflage fatigues, Velcro.] [Assessment Boundary: Mechanisms of production not included at this grade band. Focus is on utility only.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Make observations and measurements, collect data, and identify patterns that will provide evidence for explaining phenomena. (a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or solution to a problem. (b),(e),(f),(g)

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world.
- Support scientific arguments drawing on evidence, data, or a model. (c)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and synthesize across texts and other reliable media to acquire and generate appropriate scientific information. (d),(g),(h)
- Generate and communicate scientific information orally and in written formats using various forms of media and may include tables, diagrams, and charts. (d),(h)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms
- Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles that include being born (sprouting in plants), growing, developing into adults, reproducing, and eventually dying. (a)

LS3.A: Inheritance of Traits
- Many characteristics of organisms are inherited from their parents. Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. (b)

LS3.B: Variation of Traits
- Offspring acquire a mix of traits from their biological parents. Different organisms vary in how they look and function because they have different inherited information. In each kind of organism there is variation in the traits themselves, and different kinds of organisms may have different versions of the trait. (c),(d),(e)
- The environment also affects the traits that an organism develops—differences in where they grow or in the food they consume may cause organisms that are related to end up looking or behaving differently. (b)

LS4.B: Natural Selection
- Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. (f),(h),(g)

ETS2.B: Interactions of Engineering, Technology, Science, Society, and the Natural Environment
- Over time, people's needs and wants change as do their demands for new and improved technologies. (h)

Crosscutting Concepts

Patterns
Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. Cyclic patterns of change related to time can be used to make predictions. (a),(e)

Cause and Effect
Cause and effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause and effect relationship. (b),(c),(d),(f)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
People's needs and wants change over time, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. When new technologies become available, they can bring about changes in the way people live and interact with one another. (g),(h)

Connections to other DCIs in this grade-level: **4.PSE**

Articulation of DCIs across grade-levels: **1.SF, 2.ECS, 2.IOS, 4.PSE, 5.ESI, MS.LS-GDRO**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.4.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 4–5 text complexity band proficiently, with scaffolding as needed at the high end of the range.

W.4.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

SL.4.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly.

SL.4.4 Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others.

MP.7 Look for and make use of structure.

3.MD.3 Represent and interpret data.

4.PSE Processes that Shape the Earth

4.PSE Processes that Shape the Earth

Students who demonstrate understanding can:

a. **Ask testable questions about the effects of moving water on the rate of erosion under various conditions and plan and carryout investigations to observe and document the effects.** [Clarification Statement: Examples of variables to test could be angle of slope, amount of vegetation, or volume of flow.] [Assessment Boundary: Ratios should not be included in quantitative analysis.]

b. **Obtain and communicate information about how patterns in tree rings and ice cores are used as evidence to describe the recent history of Earth's climate.** [Assessment Boundary: Students not to be assessed on their understanding of deep time.]

c. **Use evidence to explain how the physical characteristics of local areas are affected by the processes of weathering and erosion, including the activities of living organisms.** [Clarification Statement: Examples of activities of living organisms could be tree planting, beaver dams, or human-built dams and waterways.]

d. **Use evidence to construct an explanation that some rocks and minerals are formed from the remains of organisms.**

e. **Use evidence from the fossil record to construct an explanation for the relationship between types of organisms living today and types of organisms that lived in the past.**

f. **Use evidence to construct explanations for how environments today may be different from past environments in which fossilized organisms once lived.** [Clarification Statement: Examples of evidence of environments that have changed could be seashell fossils found on mountains or petrified wood found in deserts.]

g. **Obtain information about the locations of a variety of Earth's features and map the geographic patterns that emerge.** [Clarification Statement: Examples of features could be volcanoes and earthquakes that are often found at the boundaries of continents and the ocean floor or major mountain chains that often form near the edges of continents.]

h. **Analyze maps and other data to determine the likelihood of geological hazards occurring in an area and evaluate the possible effects on landforms and organisms.** [Assessment Boundary: Results of analysis and evaluation are qualitative.]

i. **Construct models, based on research, to test and refine various design solutions for reducing the impacts of geological hazards.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.

- Identify scientific (testable) and non-scientific questions. (a)

Developing and Using Models

Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.

- Construct and revise models collaboratively to measure and explain frequent and regular events. (g)
- Construct a model using an analogy, example, or abstract representation to explain a scientific principle. (i)
- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a natural or designed system. (i)
- Identify limitations of models. (i)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (a)
- Make observations and measurements, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon or test a design solution. (a)

Analyzing and Interpreting Data

Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.

- Display data in tables and graphs, using digital tools when feasible, to reveal patterns that indicate relationships. (h)
- Use data to evaluate claims about cause and effect. (h)
- Compare data collected by different groups in order to discuss similarities and differences in their findings. (h)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Use quantitative relationships to construct explanations of observed events (e.g., the distribution of plants in the back yard or why some things sink and others float). (e)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Fossils provide evidence about the types of organisms (both visible and microscopic) that lived long ago and also about the nature of their environments. Fossils can be compared with one another and to living organisms according to their similarities and differences. (d),(e),(f)

ESS1.C: The History of Planet Earth

- Earth has changed over time. Understanding how landforms develop, are weathered (broken down into smaller pieces), and erode (get transported elsewhere) can help to infer the history of the current landscape. (a),(f)
- Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. (g)
- Patterns of tree rings and ice cores from glaciers can help reconstruct Earth's recent climate history. (b)

ESS2.A: Earth Materials and Systems

- Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (a),(c)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features where people live and in other areas of Earth. (g)

ESS2.C: The Roles of Water in Earth's Surface Processes

- The downhill movement of water as it flows to the ocean shapes the appearance of the land. (a)

ESS2.E: Biogeology

- Living things affect the physical characteristics of their regions (e.g., plants' roots hold soil in place, beaver shelters and human-built dams alter the flow of water, plants' respiration affects the air). Many types of rocks and minerals are formed from the remains of organisms or are altered by their activities. (c),(d)

ESS3.B: Natural Hazards

- A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (h),(i)

ETS1.B: Designing Solutions to Engineering Problems

- Research on a problem should be carried out—for example, through Internet searches, market research, or field observations—before beginning to design a solution. An often productive way to generate ideas is for people to work together to brainstorm, test, and refine possible solutions. (h),(i)

Crosscutting Concepts

Patterns

Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. Cyclic patterns of change related to time can be used to make predictions. (b),(g)

Cause and Effect

Cause and effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause and effect relationship. (a),(c),(d),(h)

Stability and Change

Some stable systems are static while others change in different ways. Some systems appear stable, but over long periods of time will eventually change. (e),(f)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

People's needs and wants change, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. When new technologies become available, they can bring about changes in the way people live and interact with one another. (i)

4.PSE Processes that Shape the Earth

4.PSE Processes that Shape the Earth *(continued)*		
▪ Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or solution to a problem. (d),(e),(f) ▪ Identify the evidence that supports an explanation. (d),(e) **Engaging in Argument from Evidence** Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world. ▪ Construct and support scientific arguments drawing on evidence, data, or a model. (c) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods. ▪ Compare and synthesize across texts and other reliable media to acquire and generate appropriate scientific information. (b),(g) ▪ Synthesize information in written text with that contained in corresponding tables, diagrams, and charts. (g) ▪ Generate and communicate scientific information orally and in written formats using various forms of media and may include tables, diagrams, and charts. (b) ▪ Use models to share findings in oral and written presentations, and extended discussions. (g)	▪ Testing a solution involves investigating how well it performs under a range of likely conditions. (i) ▪ Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (i)	

Connections to other DCIs in this grade-level: **4.LCT, 4.WAV**

Articulation of DCIs across grade-levels: **K.OTE, K.WEA, 1.PC, 2.ECS, 2.IOS, 3.WCI, 5.ESI, MS.ESS-HE, MS.ESS-WC, MS.ESS-EIP, MS.LS-NSA. MS.ETS-ED**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.4.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 4–5 text complexity band proficiently, with scaffolding as needed at the high end of the range.

W.4.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

SL.4.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly.

SL.4.2 Paraphrase portions of a text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.

MP.3 Construct viable arguments and critique the reasoning of others.

MP.7 Look for and make use of structure.

4.G.1 Draw and identify lines and angles, and classify shapes by properties of their lines and angles.

3.MD.2 Solve problems involving measurement and estimation of intervals of time, liquid volumes, and masses of objects.

4.E Energy

4. E Energy

Students who demonstrate understanding can:

a. **Construct a simple explanation for the relationship between energy and motion.** [Clarification Statement: Examples could be that a faster ball will make a louder sound when it hits the wall than a slower one or a fast car has more energy than a slow car.] [Assessment Boundary: No attempt is made to give a precise definition of energy.]

b. **Carry out investigations to provide evidence that energy is transferred from place to place by sound, light, heat, electric currents, interacting magnets, and moving or colliding objects.** [Assessment Boundary: Quantitative measurements of energy are beyond the scope of assessment.]

c. **Obtain and communicate information for how technology allows humans to concentrate, transport, and store energy for practical use.** [Clarification Statement: Examples could be batteries in electrical devices, power grids, or gasoline stations.]

d. **Design and construct a device that converts energy from one form to another using given design criteria.** [Clarification Statement: Examples of devices could be a windmill, watermill, alarm circuit, bell, or solar oven.]

e. **Design and test a solution to a problem that utilizes the transfer of electric energy in the solution using given design constraints.** [Clarification Statement: Examples of solutions could be a flashlight, electric motor, or doorbell.]

f. **Develop a model using examples to explain differences between renewable and non-renewable sources of energy.** [Assessment Boundary: Should not include climate change.]

g. **Construct simple explanations for how forces on an object cause the object to change its energy.** [Clarification Statement: Examples of explanations could include how an unbalanced force is required to put an object in motion or stop the motion of an object.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.

- Construct a model using an analogy, example, or abstract representation to explain a scientific principle or design solution. (f)
- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a designed system. (e)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Make observations, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon or test a design solution. (b),(g)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or solution to a problem. (a),(h)
- Apply scientific knowledge to solve design problems. (d)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.

- Compare and synthesize across texts and other reliable media to acquire and generate appropriate scientific and technical information. (c)
- Generate and communicate scientific and technical information orally and in written formats using various forms of media and may include tables, diagrams, and charts. (c)

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- The faster a given object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.) (a),(b)

PS3.B: Conservation of Energy and Energy Transfer

- Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (a)
- Light also transfers energy from place to place. For example, energy radiated from the sun is transferred to the earth by light. When this light is absorbed, it warms Earth's land, air, and water and facilitates plant growth. (b)
- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy (e.g., moving water driving a spinning turbine which generates electric currents). (e)

PS3.C: Relationship Between Energy and Forces

- When objects collide, the contact forces transfer energy so as to change the objects' motions. Magnets can exert forces on other magnets or on magnetizable materials, causing energy transfer between them (e.g., leading to changes in motion) even when the objects are not touching. (a),(g)

PS3.D: Energy in Chemical Processes and Everyday Life

- The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use—for example, the stored energy of water behind a dam is released so that it flows downhill and drives a turbine generator to produce electricity. (c),(d)
- It is important to be able to concentrate energy so that it is available for use where and when it is needed. For example, batteries are physically transportable energy storage devices, whereas electricity generated by power plants is transferred from place to place through distribution systems. (c)

ESS3.A: Natural Resources

- All materials, energy, and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (f)

ETS1.A: Defining Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (d),(e)

ETS1.C: Optimizing the Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (e)

Crosscutting Concepts

Energy and Matter

Matter is made of particles. Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. Energy can be transferred in various ways and between objects. (a),(b),(c),(f),(g),(h)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

People's needs and wants change over time, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. When new technologies become available, they can bring about changes in the way people live and interact with one another. (d),(e)

4.E Energy

4. E Energy *(continued)*
Connections to other DCIs in this grade-level: **4.WAV**
Articulation of DCIs across grade-levels: **K.OTE, K.WEA, 2.PP, 2.ECS, MS.PS-E, MS.PS-CR, MS.ESS-EIP, MS.ETS-ED**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.4.10** By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 4–5 text complexity band proficiently, with scaffolding as needed at the high end of the range. **W.4.2** Write informative/explanatory texts to examine a topic and convey ideas and information clearly. **W.4.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. **SL.4.1** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly. *Mathematics –* **MP.1** Make sense of problems and persevere in solving them. **MP.2** Reason abstractly and quantitatively. **MP.3** Construct viable arguments and critique the reasoning of others. **MP.7** Look for and make use of structure. **4.MD.2** Solve problems involving measurement and conversion of measuremtns from a larger unit to a smaller unit.

4. WAV Waves

4.WAV Waves

Students who demonstrate understanding can:

a. Investigate the motions of waves on the surface of water to identify patterns. [Assessment Boundary: Observations are qualitative, not quantitative.]

b. Use a model to describe the amplitude and wavelength of waves.

c. Investigate how waves affect the motions of objects to provide evidence that waves transfer energy to objects as a wave passes. [Clarification Statement: An example of evidence could be corks bobbing up and down as a wave passes.] [Assessment Boundary: Observations are qualitative not quantitative.]

d. Investigate the interaction of two waves to describe how waves add or cancel one another depending on their relative phase. [Clarification Statement: Examples of investigations could be two pebbles dropped in water or a slinky shaken at both ends to produce waves that cross.] [Assessment Boundary: The wave nature of light is not included and observations are qualitative, not quantitative.]

e. Obtain and share information about naturally occurring waves which transfer energy. [Clarification Statement: Naturally occurring waves should include ocean, sound, and seismic waves. Evidence that can be used to show transfer of energy could include coastal erosion or earthquake damage.]

f. Design, refine, and evaluate a model to solve a problem of transferring information using mechanical waves that can be decoded and communicate the design to others. [Clarification Statement: An example of transferring information could be drums that send information through sound waves.]

g. Obtain and communicate information about modern devices that are used to transmit and receive digital information. [Clarification Statement: An example of a modern device that can be used to transmit and receive digital information could be cell phones.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Construct a model using an analogy, example, or abstract representation to explain a scientific principle or design solution. (f)
- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a natural or designed system. (b)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Discuss and evaluate appropriate methods and tools for collecting data. (a)
- Make observations, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon or test a design solution. (c),(d)
- Formulate questions and predict reasonable outcomes based on patterns such as cause and effect relationships. (c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Apply scientific knowledge to solve design problems. (f)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluate the merit and accuracy of ideas and methods.
- Compare and synthesize across texts and other reliable media to acquire and/or generate appropriate scientific and technical information. (e),(g)
- Synthesize information in written text with that contained in corresponding tables, diagrams, and charts. (e)
- Critique and communicate scientific and technical information orally and in written formats using various forms of media and may include tables, diagrams, and charts. (e),(g)

Disciplinary Core Ideas

PS4.A: Wave Properties
- Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; it does not move in the direction of the wave—observe, for example, a bobbing cork or seabird—except when the water meets the beach. (Note: This grade band endpoint was moved from K–2). (a),(c)
- Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (b)
- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (d)
- Earthquakes cause seismic waves, which are waves of motion in Earth's crust. (e)

PS4.C: Information Technologies and Instrumentation
- Digitized information (e.g., the pixels of a picture) can be stored for future recovery or transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (g)

ETS1.B: Developing Possible Solutions
- There are many types of models, ranging from simple physical models to computer models. They can be used to investigate how a design might work, communicate the design to others, and compare different designs. (f)

ETS2.A: Interdependence of Science, Engineering, and Technology
- Knowledge of relevant scientific concepts and research findings is important in engineering. (f)

Crosscutting Concepts

Patterns
Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. Cyclic patterns of change related to time can be used to make predictions. (a),(b),(d)

Energy and Matter
Matter is made of particles. Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. Energy can be transferred in various ways and between objects. (c),(e)

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Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
Science and technology support each other. Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies. (f),(g)

Connections to other DCIs in this grade-level: **4.E, 4.PSE**

Articulation of DCIs across grade-levels: **1.LS, 3.IF, 5.SSS, MS.PS-WER, MS.ETS-ED**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.4.3 Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.

RI.4.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 4–5 text complexity band proficiently, with scaffolding as needed at the high end of the range.

W.4.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

SL.4.4 Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

Mathematics –

MP.1 Make sense of problems and persevere in solving them.

MP.3 Construct viable arguments and critique the reasoning of others.

MP.7 Look for and make use of structure.

4.OA.5 Generate and analyze patterns.

5.SPM Structure, Properties, and Interactions of Matter

5. SPM Structure, Properties, and Interactions of Matter

Students who demonstrate understanding can:

a. Use the model that matter is made of particles too small to be seen to describe and explain everyday phenomena. [Clarification Statement: Examples of everyday phenomena could be inflating a balloon, effect of air on large objects, or the smell of food cooking.]

b. Investigate physical properties of materials and use the properties to distinguish one material from another. [Clarification Statement: Examples of physical properties can include salt dissolving in water while sand does not; copper wire conducting electric current and shoelaces do not; a metal spoon conducting heat and a wooden spoon does not.]

c. Investigate the interaction of two or more substances to provide evidence that when different substances are mixed, one or more new substances with different properties may or may not be formed depending on the substances and the temperature. [Clarification Statement: Examples of interactions forming new substances can include mixing baking soda and vinegar. Examples of interactions not forming new substances can include mixing baking soda and water.]

d. Plan and carry out investigations to determine the effect on the total weight of a substance when the substance changes shape, phase, and/or is dissolved. [Assessment Boundary: No attempt should be made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.]

e. Investigate and determine the effect on the total weight of matter when substances interact to form new substances. [Clarification Statement: Examples of interacting substances can include putting wet steel wool in a closed container and letting it rust, and mixing vinegar and milk in a closed container.] [Assessment boundary: Mass and weight are not distinguished at this grade level.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent on events and design solutions.

- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a natural or designed system. (a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (c),(d),(e)
- Make observations and measurements, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon or test a design solution. (b),(c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 3–5 level builds on K–2 and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.

- Use standard units to measure area, volume, weight, and temperature. (c),(d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in condensation, fog, and, by extension, also in clouds or the contrails of a jet. (a)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (e.g., sugar in solution, evaporation in a closed container). (d)
- Measurements of a variety of properties (e.g., hardness, reflectivity) can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (b)

PS1.B: Chemical Reactions

- When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. (c)
- No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (d),(e)

Crosscutting Concepts

Energy and Matter
Matter is made of particles. Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. Energy can be transferred in various ways and between objects. (a),(d),(e)

Structure and Function
Different materials have different substructures, which can sometimes be observed. Substructures have shapes and parts that serve functions. (b),(c)

Connections to other DCIs in this grade-level: **5.MEE**

Articulation of DCIs across grade-levels: **2.SPM, MS.PS-SPM, MS.PS-CR**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.5.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.3 Construct viable arguments and critique the reasoning of others.

MP.7 Look for and make use of structure.

5.OA.1 Write and interpret numerical expressions.

4.MD.2 Solve problems involving measurement and conversion of measurements from a larger unit to a smaller unit.

5.MEE Matter and Energy in Ecosystems

5.MEE Matter and Energy in Ecosystems

Students who demonstrate understanding can:

- **a. Construct models of food webs to explain the interrelationship among plants, animals, and fungi within ecosystems.**
- **b. Use models to trace the cycling of particles of matter between the air and soil and among plants, animals, and microbes.** [Assessment Boundary: The emphasis is on students applying the particle model to explain how matter cycles; it does not include the chemistry of metabolism.]
- **c. Use models to describe how decomposition eventually returns (recycles) some materials back to the soil for plants to use.**
- **d. Ask questions about how food provides animals with the materials they need for body repair and growth and is digested by animals to release the energy they need to maintain body warmth and allow for motion.**
- **e. Obtain and communicate information tracing the source of energy for burning fuel or digesting food back to energy from the sun that was captured by plants through a chemical process.**
- **f. Use models to communicate that plants obtain matter to grow chiefly from the air and water, and energy to grow from the sun.** [Assessment Boundary: Details of photosynthesis are not included.]
- **g. Plan and carry out investigations to determine the role of light in plant growth.** [Assessment Boundary: Details of photosynthesis are not included.]
- **h. Design and construct a model to describe the interactions of systems within an ecosystem in terms of the flow of energy, cycling of matter, and the conditions for a healthy ecosystem.** [Clarification Statement: Examples of a healthy ecosystem are ones in which multiple species of different types are able to meet their needs or no new invasive species are introduced.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.
- Ask questions based on careful observations of phenomena and information. (d)
- Ask questions of others to clarify ideas or request evidence. (d)

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Construct and revise models collaboratively to measure and explain frequent and regular events. (f)
- Construct a model using an analogy, example, or abstract representation to explain a scientific principle. (b)
- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a natural or designed system. (a),(c),(h)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Make observations and measurements, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon. (g)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and synthesize across texts and other reliable media to acquire and generate appropriate scientific and technical information. (e)
- Synthesize information in written text with that contained in corresponding tables, diagrams, and charts. (e)

Disciplinary Core Ideas

PS3.D: Energy in Chemical Processes and Everyday Life
- Food and fuel also release energy when they are digested or burned. When machines or animals "use" energy (e.g., to move around), most often the energy is transferred to heat the surrounding environment. (e)
- The energy released by burning fuel or digesting food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (e),(f)

LS1.C: Organization for Matter and Energy Flow in Organisms
- Animals and plants alike generally need to take in air and water, animals must take in food, and plants need light and minerals. Food provides animals with the materials they need for body repair and growth and is digested to release the energy they need to maintain body warmth and for motion. Anaerobic life, such as bacteria in the gut, functions without air. (d),(g)
- Plants acquire their material for growth chiefly from air and water and process matter they have formed to maintain their internal conditions (e.g., at night). (f)

LS2.A: Interdependent Relationships in Ecosystems
- The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Either way, they are "consumers." Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil for plants to use. (a),(b),(c)
- Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (h)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. (b)
- Organisms obtain gases, water, and minerals from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (b),(h)

Crosscutting Concepts

Systems and System Models
A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. A system can be described in terms of its components and their interactions. (a),(h)

Energy and Matter
Matter is made of particles. Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. Energy can be transferred in various ways and between objects. (b),(c),(d),(e),(f),(g)

Connections to other DCIs in this grade-level: **5.SPM, 5.ESI**

Articulation of DCIs across grade-levels: **K.OTE, 2.IOS, 3.EIO, 4.E, MS.LS-IRE, MS.LS-MEOE, MS.PS-E**

Common Core State Standards Connections; [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.
RI.5.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 4–5 text complexity band independently and proficiently.
W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.
SL.5.4 Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.3 Construct viable arguments and critique the reasoning of others.
MP.4 Model with mathematics.
5.G.2 Graph points on the coordinate plane to solve real-world and mathematical problems.

5.ESI Earth Systems and Their Interactions

5.ESI Earth Systems and Their Interactions

Students who demonstrate understanding can:

a. Obtain and communicate information about the various forms of water on Earth. [Clarification Statement: The forms of water on Earth that students will address include vapor, fog or clouds in the atmosphere; rain or snow falling from clouds; ice, snow, and running water on land; moisture in soil and salt water in the ocean; and groundwater beneath the surface.] [Assessment Boundary: Focus is on the existence of different forms of water, not the cycling.]

b. Use mathematical thinking to compare the relative abundance of salt water to fresh water and analyze data to identify the major locations of fresh water.

c. Construct models to describe systems interactions for the geosphere, hydrosphere, atmosphere, and biosphere and identify the limitations of the models.

d. Obtain and share information on the role of the ocean in supporting a variety of ecosystems and organisms, shaping landforms, and influencing climate.

e. Construct models to describe weather and climate patterns which are produced by the interactions among the atmosphere, the ocean, and landforms.

f. Obtain, evaluate, and communicate information describing the impacts human activities have on Earth's systems and generate examples of actions individuals and communities have taken to conserve Earth's resources and environments.

g. Design and evaluate a process or product to minimize unwanted outcomes of human activities on Earth's systems, while increasing benefits and meeting societal demands. [Clarification Statement: Examples of processes or products could be designing a cost-effective water filtration system that reduces pollutants in a river; or conducting an energy audit and developing a plan to reduce energy use.]

h. Provide evidence to explain how increases in Earth's temperature can affect humans and other organisms. [Clarification Statement: Examples of effects on humans and other organisms can include changes in crop growing seasons, changes in coral reefs, and loss of habitat for penguins.] [Assessment Boundary: The Greenhouse effect and details of climate change are not included here.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.

- Construct and revise models collaboratively to measure and explain frequent and regular events. (c),(e)
- Identify limitations of models. (c)

Analyzing and Interpreting Data

Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.

- Use data to evaluate claims about cause and effect relationships. (e)
- Use data to evaluate and refine design solutions. (g)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 3–5 level builds on K–2 and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.

- Analyze simple data sets for patterns that suggest relationships. (b)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.

- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or solution to a problem. (f),(g),(h)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.

- Compare and synthesize across texts and other reliable media to acquire and generate appropriate scientific and technical information. (a),(d),(f)
- Synthesize information in written text with that contained in corresponding tables, diagrams, and charts. (a)
- Generate and communicate scientific and technical information orally and in written formats using various forms of media and may include tables, diagrams, and charts. (d),(f)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems

- Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. (c)
- The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. (d)
- Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (d),(e)
- Human activities affect Earth's systems and their interactions at its surface. (f),(g)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water is found almost everywhere on Earth: as vapor; as fog or clouds in the atmosphere; as rain or snow falling from clouds; as ice, snow, and running water on land and in the ocean; and as groundwater beneath the surface. (a)
- Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (b)

ESS3.C: Human Impacts on Earth Systems

- Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. For example, they are treating sewage, reducing the amounts of materials they use, and regulating sources of pollution such as emissions from factories and power plants or the runoff from agricultural activities. (f),(g)

ESS3.D: Global Climate Change

- If Earth's global mean temperature continues to rise, the lives of humans and other organisms will be affected in many different ways. (h)

ETS2.B: Interactions of Engineering, Technology, Science, Society, and the Natural Environment.

- Engineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), to decrease known risks (e.g., seatbelts in cars), and to meet societal demands (e.g., cell phones). (g)

Crosscutting Concepts

Systems and System Models

A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. A system can be described in terms of its components and their interactions. (a),(c),(d),(e),(f),(h)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

People's needs and wants change over time, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. When new technologies become available, they can bring about changes in the way people live and interact with one another. (g)

5.ESI Earth Systems and Their Interactions *(continued)*
Connections to other DCIs in this grade-level: **5.MEE**
Articulation of DCIs across grade-levels: **K.OTE, 4.PSE, 4.LCT, MS.ESS-HI, MS.ESS-EIP, MS.ESS-ESP, MS.ETS-ETSS**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.5.3** Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text. **RI.5.9** Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. **W.5.2** Write informative/explanatory texts to examine a topic and convey ideas and information clearly. **SL.5.2** Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally. *Mathematics –* **MP.1** Make sense of problems and persevere in solving them. **MP.2** Reason abstractly and quantitatively. **MP.3** Construct viable arguments and critique the reasoning of others. **4.MD.2** Solve problems involving measurement and conversion of measurements from a larger unit to a smaller unit.

5.SSS Stars and the Solar System

5.SSS Stars and the Solar System

Students who demonstrate understanding can:

a. **Obtain and communicate information about the sizes of stars, including the sun, and their distances from Earth to explain their apparent brightnesses.**
b. **Provide evidence that Earth is spherical and the gravitational force of the Earth causes objects near the surface to be pulled toward the planet's center.**
c. **Use a model of a rotating, spherical Earth and the relative positions of the sun and moon to explain patterns in daily changes in length and direction of shadows, day and night, and the phases of the moon.** [Assessment Boundary: Seasons are not to be assessed.]
d. **Develop explanations for how patterns in the positions of stars and constellations can be used to navigate on Earth.**
e. **Gather evidence to investigate how lenses bend light and obtain information about the ways technology has used lenses to improve our ability to see objects.** [Clarification Statement: Examples of technology using lenses could include telescopes, microscopes, eye glasses, and jeweler's loupes.] [Assessment Boundary: Quantitative details of refraction not to be included.]
f. **Obtain, evaluate, and communicate information about the roles of science and technology in the design process for developing and refining devices to understand the universe.** [Clarification Statement: Examples of devices could include telescopes, computers and spacecraft.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions.
- Construct and revise models collaboratively to measure and explain frequent and regular events. (c)
- Use simple models to describe phenomena and test cause and effect relationships concerning the functioning of a natural or designed system. (c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Make observations and measurements, collect appropriate data, and identify patterns that provide evidence to explain a phenomenon or test a design solution. (e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or solution to a problem. (d)

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world.
- Construct and support scientific arguments drawing on evidence, data, or a model. (b)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods.
- Compare and synthesize across reliable texts and other reliable media to acquire and generate appropriate scientific and technical information. (a),(f)
- Synthesize information in written text with that contained in corresponding tables, diagrams, and charts. (a)
- Generate and communicate scientific information orally and in written formats using various forms of media and may include tables, diagrams, and charts. (a)

Disciplinary Core Ideas

PS2.B: Types of Interactions
- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (b)

PS4.B: Electromagnetic Radiation
- A great deal of light travels through space to Earth from the sun and from distant stars. Because lenses bend light beams, they can be used, singly or in combination, to provide magnified images of objects too small or too far away to be seen with the naked eye. (a),(e)

PS4.C:Information Technologies and Instrumentation
- Lenses can be used to make eyeglasses, telescopes, or microscopes in order to extend what can be seen. The design of such instruments is based on understanding how the path of light bends at the surface of a lens. (e)

ESS1.A: The Universe and its Stars
- The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their size and distance from Earth. (a)

ESS1.B: Earth and the Solar System
- The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the moon; and different positions of the sun, moon, and stars at different times of the day, month, and year. *[Note: Seasons are addressed in middle school.]* (c)
- Some objects in the solar system can be seen with the naked eye. Planets in the night sky change positions and are not always visible from Earth as they orbit the sun. Stars appear in patterns called constellations, which can be used for navigation and appear to move together across the sky because of Earth's rotation. (d)

ETS2.A: Interdependence of Science, Engineering, and Technology
- Tools and instruments (e.g., rulers, balances, thermometers, graduated cylinders, telescopes, microscopes) are used in scientific exploration to gather data and help answer questions about the natural world. Engineering design can develop and improve such technologies (e),(f)

Crosscutting Concepts

Patterns
Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. Cyclic patterns of change related to time can be used to make predictions. (c),(d)

Cause and Effect
Cause and effect relationships are routinely identified, tested, and used to explain change. Events that occur together with regularity might or might not be a cause and effect relationship. (b)

Scale, Proportion, and Quantity
Natural objects and observable phenomena exist from the very small to the immensely large. (a)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
Science and technology support each other. Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies. (e),(f)

Connections to other DCIs in this grade-level: **N/A**

Articulation of DCIs across grade-levels: **1.PC, 3.SFS, 3.IF, 4.WAV, 4.PSE, MS.ESS-SS, MS.PS-WER, MS.PS-IF, MS.ETS-ETSS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.
SL.5.2 Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.3 Construct viable arguments and critique the reasoning of others.
MP.7 Look for and make use of structure.
5.G.1 Graph points on the coordinate plane to solve real-world and mathematical problems.

MS.LS-SFIP Structure, Function, and Information Processing

MS.LS-SFIP Structure, Function, and Information Processing

Students who demonstrate understanding can:

a. **Investigate and present evidence that the structure of cells in both unicellular and multicellular organisms is related to how cells function.** [Assessment Boundary: Students conduct, not design, investigations.]
b. **Investigate and generate evidence that unicellular and multicellular organisms survive by obtaining food and water, disposing of waste, and having an environment in which to live.**
c. **Construct an explanation for the function of specific parts of cells including: nucleus, chloroplasts, and mitochondria and the structure of the cell membrane and cell wall for maintaining a stable internal environment.**
d. **Construct models and representations of body systems to demonstrate how multiple interacting subsystems and structures work together to accomplish specific functions.** [Clarification Statement: Representations are specific to the interactions of the systems and focus on the following systems: excretory, digestive, respiratory, and nervous systems.] [Assessment Boundary: The focus is on the interaction of subsystems within the system, not the mechanism of each body system itself.]
e. **Provide explanations of how sense receptors respond to stimuli by sending messages to the brain to be processed for immediate behavior or stored as information.**
f. **Communicate an explanation for how the storage of long-term memories requires changes in the structure and function of millions of interconnected nerve cells in the brain.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (a),(b)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (c),(e)
- Construct explanations from models or representations. (c)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluating the merit and validity of ideas and methods.
- Gather, read, and explain information from appropriate sources and evaluate the credibility of the publication, authors, possible bias of the source, and methods used. (f)

Disciplinary Core Ideas

LS1.A: Structure and Function
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (a)
- Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live. (b)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (c)
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (d)

LS1.D: Information Processing
- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. (e)
- The signals are then processed in the brain, resulting in immediate behaviors or memories. Changes in the structure and functioning of many millions of interconnected nerve cells allow combined inputs to be stored as memories for long periods of time. (f)

Crosscutting Concepts

Systems and System Models
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (b),(d),(e)

Structure and Function
Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (a),(c),(f)

Connections to other topics in this grade level: **MS.PS-CR**

Articulation across grade-levels: **3.SFS, HS.LS-SFIP**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
RI.6.7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.
RI.6.8 Trace and evaluate the argument and specific claims in a text, distinguishing claims that are supported by reasons and evidence from claims that are not.
RI.7.8 Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims.
RI.8.8 Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient; recognize when irrelevant evidence is introduced.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.6 Attend to precision.
7.SP.1,2 Use random sampling to draw inferences about a population.

MS.LS-MEOE Matter and Energy in Organisms and Ecosystems

MS.LS-MEOE   Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

a. Develop an explanation for the role of photosynthesis in the cycling of matter and flow of energy on Earth. [Assessment Boundary: Limited to the explanation related to water, carbon dioxide, and light energy being used to produce sugars and release oxygen NOT the chemical equation for photosynthesis.]

b. Investigate the cycling of matter among living and nonliving parts of ecosystems to explain the flow of energy and conservation of matter. [Clarification Statement: Investigations are qualitative observations of the cycling of water, carbon, and oxygen in the environment.]

c. Use models to explain the transfer of energy into, out of, and within ecosystems. [Assessment Boundary: Only light, chemical, and thermal energy need to be addressed with an emphasis that the total amount of energy does not change.]

d. Construct and communicate models of food webs that demonstrate the transfer of matter and energy among organisms within an ecosystem. [Clarification Statement: Models of food webs should include producers, consumers and decomposers.]

e. Use evidence to support an explanation that matter is conserved when molecules from food react with oxygen in the environment and cycle repeatedly between living and non-living components of ecosystem.

f. Use evidence to support arguments that changing any physical or biological component of an ecosystem may result in shifts in the populations of species in the ecosystem.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (c),(d)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions under a range of conditions. (b)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (a)
- Construct explanations from models or representations. (e)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (f)

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (a)
- Animals obtain food from eating plants or eating other animals. (d)
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth or to release energy. (e)
- In most animals and plants, oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce carbon-dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not need oxygen. (c)

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

- Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (b),(c),(d)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (f)

Crosscutting Concepts

Systems and System Models-
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (c)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (a),(b),(e)

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (d)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (f)

Connections to other topics in this grade-level: **MS.ESS-HE, MS.ESS-ESP, MS.PS-SPM, MS.PS-ECT, MS.PS-CR**

Articulation across grade-levels: **3.SFS, 5.MEE, HS.LS-MEOE, HS.LS-IRE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

W.6.8 Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.

W.7.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others.
MP.4 Model with mathematics.
5.OA Analyze patterns and relationships.
6.SP Summarize and describe distributions.

MS.LS-IRE Interdependent Relationships in Ecosystems

MS.LS-IRE Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

a. **Use a model to demonstrate the effect of resource availability on organisms and populations of organisms in an ecosystem.**
b. **Construct explanations to describe competitive, predatory, and mutually beneficial interactions as patterns across various ecosystems.**
c. **Ask researchable questions about the ways organisms obtain matter and energy across multiple and varied ecosystems.** [Assessment Boundary: Biochemical details of photosynthesis and cellular respiration are not to be treated in terms of mechanism.]
d. **Use models to explain the role of biodiversity in ecosystems.**
e. **Use evidence to construct arguments for how biodiversity can influence humans' resources as well as ecosystem services that humans rely on.** [Clarification Statement: Examples of humans' resources include food, energy, medicines. Ecosystem services can include water purification and recycling.]
f. **Pose questions about patterns in social interactions and grouping behaviors of animals that contribute to survival advantages.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions.
- Ask questions that arise from phenomena, models, or unexpected results. (c),(f)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)
- Modify models – based on their limitations – to increase detail or clarity, or to explore what will happen if a component is changed. (a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why data are adequate for the explanation or conclusion. (b)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (e)

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (a),(c)
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (b)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (d)

LS2.D: Social Interactions and Group Behavior
- Groups may form because of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species-specific). They engage in a variety of signaling behaviors to maintain the group's integrity or to warn of threats. Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members. (f)

LS4.D: Biodiversity and Humans
- Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). (d)
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (e)

Crosscutting Concepts

Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (b),(f)

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(e)

Systems and System Models
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (d)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (c)

Connections to other topics in this grade-level: **MS.ESS-HE, MS.ESS-HI, MS.ETS-ETSS**

Articulation across grade-levels: **3.EIO, 5.MEE, HS.LS-IRE, HS.LS-MEOE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.6.3 Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.
SL.7.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.
WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others.
5.OA Analyze patterns and relationships.
7.SP.3 Draw informal comparative inferences about two populations.

MS.LS-NSA Natural Selection and Adaptations

MS.LS-NSA Natural Selection and Adaptations

Students who demonstrate understanding can:

- **a. Analyze and interpret patterns of change in fossils to provide evidence of the history of life on Earth.**
- **b. Construct explanations for the anatomical similarities and differences between fossils of once-living organisms and organisms living today.** [Clarification Statement: Students should use the record of evolutionary descent between ancient and modern-day organisms.]
- **c. Develop explanations for why most individual organisms, as well as some entire species of organisms, that lived in the past were never fossilized.** [Assessment Boundary: The process of fossilization is not treated in any detail within the life sciences but addressed in the Earth sciences.]
- **d. Recognize and compare patterns in the embryological development across different species to identify relationships not evident in the fully formed anatomy.** [Assessment Boundary: Limited to general characteristics of embryological development among species.]
- **e. Communicate explanations for how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment which tends to increase these traits in the population.**
- **f. Use mathematical models to explain how natural selection over many generations results in changes within species in response to environmental conditions that increase or decrease certain traits in a population.** [Clarification Statement: Population data for organisms over time showing trends in numbers of individuals with specific traits.] [Assessment Boundary: Data should be provided to students.]
- **g. Obtain and evaluate information about how two populations of the same species in different environments have evolved to become separate species.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Distinguish between causal and correlational relationships. (a)
- Use graphical displays to analyze data in order to identify linear and nonlinear relationships. (d)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical concepts such as ratios, averages, basic probability, and simple functions, including linear relationships to analyze data. (f)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (b)
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (c)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluating the merit and validity of ideas and methods.

- Generate and communicate ideas using scientific language and reasoning. (e)
- Gather, read, and explain information from appropriate sources and evaluate the credibility of the publication, authors, possible bias of the source, and methods used. (g)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Fossils are mineral replacements, preserved remains, or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of the Earth itself but also of changes in organisms whose fossil remains have been found in those layers. (a)
- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. Because of the conditions necessary for their preservation, not all types of organisms that existed in the past have left fossils that can be retrieved. (c)
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (b)
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (d)

LS4.B: Natural Selection

- Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population, and the suppression of others. (e),(f)

LS4.C: Adaptation

- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. (g)
- Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (f)
- In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to be separate species. (g)

Crosscutting Concepts

Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a),(b),(d)

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (c),(e),(f)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (g)

Connections to other topics in this grade-level: **MS.ESS-HE**

Articulation across grade-levels: **3.EIO, 3.SFS, 4.PSE, 4.LCT, HS.LS-NSE, HS.LS-IRE, HS.PS-NP**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.6 Attend to precision.
MP.4 Model with mathematics.
5.OA Analyze patterns and relationships.
6.EE Apply and extend previous understandings of arithmetic to algebraic expressions.
Reason about and solve one-variable equations and inequalities.
7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.LS-GDRO Growth, Development, and Reproduction of Organisms

MS.LS-GDRO Growth, Development, and Reproduction of Organisms

Students who demonstrate understanding can:

a. **Use evidence to support an explanation of how environmental and genetic factors affect the growth of organisms.** [Clarification Statement: The emphasis is on the impact of factors in terms of cause and effect, not the mechanism (e.g., abundant food leads to more significant growth, offspring of large breeds of dogs are larger than the offspring of small dogs).]

b. **Investigate and present evidence that plants continue to grow throughout their life through the production of new plant matter via photosynthesis.** [Assessment Boundary: Reproduction is not treated in any detail here, for more specifics of grade level see DCI LS3.A.]

c. **Use models to construct an explanation of how the genetic contribution from each parent through sexual reproduction results in variation in offspring and how asexual reproduction results in offspring with identical genetic information.** [Assessment Boundary: The emphasis is on the impact of gene transmission in reproduction, not the mechanism of the gene interactions.]

d. **Plan and conduct investigations to gather evidence for the relationship among specialized plant structures, specific animal behaviors, and the successful reproduction of the plant.** [Clarification Statement: Examples of evidence of successful reproduction of plants could include placement of stamen and bees gathering nectar, hard shells on pine nuts and squirrels burying nuts.]

e. **Use empirical evidence to support an argument for how characteristic animal behaviors affect the probability of successful reproduction.** [Clarification Statement: Examples of animal behaviors could include birds building nests to protect young, brown trout spawning in late fall when predators are less active.]

f. **Provide explanations of how changes (mutations) to genes, which are located on chromosomes, affect specific inherited traits resulting in harmful, beneficial, or neutral effects.**

g. **Provide an explanation for the relationship among changes (mutations) to genes, changes to the formation of proteins, and the effect on the structure and function of the organism and thereby traits.**

h. **Communicate explanations of ways technologies enable humans to influence the inheritance of certain traits in plants and animals.** [Clarification Statement: Examples of human influence could be breeds of cattle for various purposes, disease resistant crops, genetically modified organisms.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Modify models—based on their limitations—to increase detail or clarity, or to explore what will happen if a component is changed. (c)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (b)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (b)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a),(d),(f),(g)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (e)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluating the merit and validity of ideas and methods.

- Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions, and competing information. (h)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (c)
- Animals engage in characteristic behaviors that increase the odds of reproduction. (e)
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. (d)
- Plant growth can continue throughout the plant's life through production of plant matter in photosynthesis. (b)
- Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range. (a)

LS3.A: Inheritance of Traits

- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. (c),(f)
- Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual (e.g., human skin color results from the actions of proteins that control the production of the pigment melanin). (c)
- Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. (f),(g)
- Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair). Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited or (more rarely) from mutations. (c)

LS3.B: Variation of Traits

- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. (c)
- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism. (f)

LS4.B: Natural Selection

- In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (h)

Crosscutting Concepts

Cause and Effect

Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(b),(c),(d),(e),(f)

Structure and Function

Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (d),(g)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies from region to region and over time. (h)

MS.LS-GDRO Growth, Development, and Reproduction of Organisms *(continued)*
Connections to other topics in this grade-level: **MS.PS-CR**
Articulation across grade-levels: **4.LCT, HS.LS-IVT, HS.LS-NSE**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **W.6.1** Write arguments to support claims with clear reasons and relevant evidence. **W.7.1** Write arguments to support claims with clear reasons and relevant evidence. **RI.6.7** Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue. **WHST.7** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.3** Construct viable arguments and critique the reasoning of others. **5.OA** Analyze patterns and relationships. **6.EE** Represent and analyze quantitative relationships between dependent and independent variables. **7.SP.1,2** Use random sampling to draw inferences about a population

HS.LS-SFIP Structure, Function, and Information Processing

HS.LS-SFIP Structure, Function, and Information Processing

Students who demonstrate understanding can:

a. Obtain and communicate information explaining how the structure and function of systems of specialized cells within organisms help them perform the essential functions of life. [Assessment Boundary: Limited to conceptual understanding of chemical reactions that take place between different types of molecules such as water, carbohydrates, lipids, and nucleic acids.]

b. Communicate information about how DNA sequences determine the structure and function of proteins. [Assessment Boundary: Limited to conceptual understanding of how the sequence of nitrogen bases in DNA determine the amino acid sequence and the structure and function of the protein it codes for, not the actual protein structure.]

c. Develop and use models to explain the hierarchical organization of interacting systems working together to provide specific functions within multicellular organisms. [Clarification Statement: Levels of organization should include cells, tissues, organs, systems, and organisms.] [Assessment Boundary: The focus is on the basic organization of systems across several levels of organization.]

d. Use modeling to explain the function of positive and negative feedback mechanisms in maintaining homeostasis that is essential for organisms. [Assessment Boundary: The focus is on conceptual models explaining examples of both types of feedback systems.]

e. Use evidence to support explanations for the relationship between a region of the brain and the primary function of that region. [Clarification Statement: Conceptual understanding that the brain is divided into several distinct regions and circuits, each of which primarily serves dedicated functions (e.g., visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, decision making about actions to take in the event of certain inputs).]

f. Gather and communicate information to explain the integrated functioning of all parts of the brain for successful interpretation of inputs and generation of behaviors. [Assessment Boundary: Conceptual understanding is limited to the structure and function of the brains of complex organisms.]

g. Analyze and interpret data to identify patterns of behavior that motivate organisms to seek rewards, avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (c),(d)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (c),(d)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. (g)
- Evaluate the impact of new data on a working explanation of a phenomenon or design solution. (g)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (a),(b),(e),(f)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (a),(b),(e),(f)

Disciplinary Core Ideas

LS1.A: Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as water, proteins, carbohydrates, lipids, and nucleic acids. (a)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (b)
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (c)
- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Outside that range (e.g. at too high or too low external temperature, with too little food or water available) the organism cannot survive. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (d)

LS1.D: Information Processing

- In complex animals, the brain is divided into several distinct regions and circuits, each of which primarily serves dedicated functions, such as visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, and decision making about actions to take in the event of certain inputs. (e)
- In addition, some circuits give rise to emotions and memories that motivate organisms to seek rewards, avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species (e.g., mixed herds of mammals, mixed flocks of birds). (g)
- The integrated functioning of all parts of the brain is important for successful interpretation of inputs and generation of behaviors in response to them. (f)

Crosscutting Concepts

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. (g)

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (f)

Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (c)

Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (a),(b),(e)

Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (d)

HS.LS-SFIP Structure, Function, and Information Processing
Connections to other topics in this grade-level: **HS.ESS-CC, HS.PS-CR, HS.PS-E, HS.ETS-ETSS**
Articulation across grade-levels: **MS.LS-SFIP**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **SL.9-10.2** Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. **RST.9-10.9** Compare and contrast findings presented in a text to those from other sources (including their own experiments), nothing when the findings support or contradict previous explanations or accounts. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. **RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *Mathematics –* **S.ID** Summarize, represent, and interpret data on two categorical and quantitative variables **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.LS-MEOE Matter and Energy in Organisms and Ecosystems

HS.LS-MEOE Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

a. Construct a model to support explanations of the process of photosynthesis by which light energy is converted to stored chemical energy. [Clarification Statement: Models may include diagrams and chemical equations. The focus should be on the flow of matter and energy through plants.] [Assessment Boundary: Limited to the inputs and outputs of photosynthesis and chemosynthesis, not the specific biochemical steps involved.]

b. Construct an explanation of how sugar molecules that contain carbon, hydrogen, and oxygen are combined with other elements to form amino acids and other large carbon-based molecules. [Clarification Statement: Explanations should include descriptions of how the cycling of these elements provide evidence of matter conservation.] [Assessment Boundary: Focus is on conceptual understanding of the cycling of matter and the basic building blocks of organic compounds, not the actual process.]

c. Use a model to explain cellular respiration as a chemical process whereby the bonds of food molecules and oxygen molecules are broken and bonds in new compounds are formed that result in a net transfer of energy. [Assessment Boundary: Limited to the conceptual understanding of the inputs and outputs of metabolism, not the specific steps.]

d. Evaluate data to compare the energy efficiency of aerobic and anaerobic respiration within organisms. [Assessment Boundary: Limited to a comparison of ATP input and output.]

e. Use data to develop mathematical models to describe the flow of matter and energy between organisms and the ecosystem. [Assessment Boundary: Use data on energy stored in biomass that is transferred from one trophic level to another.]

f. Communicate descriptions of the roles of photosynthesis and cellular respiration in the carbon cycle specific to the carbon exchanges among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

g. Provide evidence to support explanations of how elements and energy are conserved as they cycle through ecosystems and how organisms compete for matter and energy. [Clarification Statement: Elements included can include carbon, oxygen, hydrogen, and nitrogen.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a),(c),(e)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (a),(c)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (e)
- Examine merits and limitations of various models in order to select or revise a model that best fits the evidence or the design criteria. (a),(c)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative claims regarding the relationship between dependent and independent variables. (g)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (g)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (b),(g)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (f)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (f)

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (a),(b),(g)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (b),(c)
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. For example, aerobic (in the presence of oxygen) cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. (c),(d)
- Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. (d)
- Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment. (c)
- Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems. (g)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (c),(e)
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain. (e)
- The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; (g)
- Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (b),(e)
- Competition among species is ultimately competition for the matter and energy needed for life. (g)
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (f)

Crosscutting Concepts

Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (f),(g)

Energy and Matter

The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (a),(b),(c),(d),(e)

HS.LS-MEOE Matter and Energy in Organisms and Ecosystems *(continued)*
Connections to other topics in this grave-level: **HS.ESS-HS, HS.PS-CR, HS.PS-E, HS.PS-SPM**
Articulation across grade-levels: **MS.LS-MEOE, MS.LS-IRE**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.9-10.1** Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text. **RI.9-10-8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient identify false statements and fallacious reasoning. **RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **WHST.9** Draw evidence from informational texts to support analysis, reflection, and research. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.4** Model with Mathematics. **MP.5** Use appropriate tools strategically. **S.ID** Summarize, represent, and interpret data on a single count or measurement variable. **F.BF** Build a function that models a relationship between two quantities. **N-Q** Reason quantitatively and use units to solve problems.

HS.LS-IRE Interdependent Relationships in Ecosystems

HS.LS-IRE Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

a. **Evaluate data to explain resource availability and other environmental factors that affect carrying capacity of ecosystems.** [Clarification Statement: The explanation could be based on computational or mathematical models. Environmental factors should include availability of living and nonliving resources and from challenges (e.g., predation, competition, disease).]

b. **Design solutions for creating or maintaining the sustainability of local ecosystems.**

c. **Construct and use a model to communicate how complex sets of interactions in ecosystems maintain relatively consistent numbers and types of organisms for long periods of time when conditions are stable.**

d. **Construct arguments from evidence about the effects of natural biological or physical disturbances in terms of the time needed to reestablish a stable ecosystem and how the new system differs from the original system.** [Clarification Statement: Computational models could be used to support collect evidence to support the argument.]

e. **Use evidence to construct explanations and design solutions for the impact of human activities on the environment and ways to sustain biodiversity and maintain the planet's natural capital.** [Clarification Statement: Explanations and solutions should include anthropogenic changes (e.g., habitat destruction, pollution, introduction of invasive species, overexploitation, climate change).]

f. **Argue from evidence obtained from scientific literature the role group behavior has in increasing the chances of survival for individuals and their genetic relatives.**

g. **Plan and carry out investigations to make mathematical comparisons of the populations and biodiversities of two similar ecosystems at different scales.** [Clarification Statement: Students compare, mathematically, the biodiversity of a small ecosystem to a large ecosystem (e.g., woodlot to a forest, small pond near a city to a wetland estuary).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9-12 builds on K-8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Construct, revise, and use models to predict and explain relationships between systems and their components. (c)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (c)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects and ensure the investigation's design has controlled for them. (g)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative claims regarding the relationship between dependent and independent variables. (b),(e)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (e)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e)
- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (b),(e)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9-12 builds from K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of arguments. (d),(f)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9-12 builds on 6-8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (a)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (a)

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (a),(g)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. (c)
- If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. (d)
- Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (a),(d)
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (e)

LS2.D: Social Interactions and Group Behavior

- Animals, including humans, having a strong drive for social affiliation with members of their own species and will suffer, behaviorally as well as physiologically, if reared in isolation, even if all their physical needs are met. Some forms of affiliation arise from the bonds between offspring and parents. Other groups form among peers. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (f)

LS4.D: Biodiversity and Humans

- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital. (d),(e)
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (b),(e)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(f)

Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Patterns observable at one scale may not be observable or exist at other scales. Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (g)

Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (b),(c),(d),(e)

HS.LS-IRE Interdependent Relationships in Ecosystems *(continued)*
Connections to other topics in this grade-level: **HS.ESS-HE, HS.ESS-ES, HS.ESS-HS**
Articulation across grade-levels: **MS.LS-IRE, MS.LS-NSA, MS.LS-MEOE**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.9-10.1** Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text. **RI.9-10-8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient identify false statements and fallacious reasoning. **W.9-10.1** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **W.11-12.1** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **SL.9-10.2** Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. **RST.9-10.10** By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently. *Mathematics –* **MP.1** Make sense of problems and persevere in solving them. **MP.3** Construct viable arguments and critique the reasoning of others. **N-Q** Reason quantitatively and use units to solve problems.

HS.LS-NSE Natural Selection and Evolution

HS.LS-NSE Natural Selection and Evolution

Students who demonstrate understanding can:

a. **Use models to explain how the process of natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the selection of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Mathematical models may be used to communicate the explanation or to generate evidence supporting the explanation.]

b. **Use evidence to explain the process by which natural selection leads to adaptations that result in populations dominated by organisms that are anatomically, behaviorally, and physiologically able to survive and/or reproduce in a specific environment.** [Assessment Boundary: Evidence should center on survival advantages of selected traits for different environmental changes such as temperature, climate, acidity, light.]

c. **Analyze and interpret data to explain the process by which organisms with an advantageous heritable trait tend to increase in numbers in future generations; but organisms that lack an advantageous heritable trait tend to decrease in numbers in future generations.**

d. **Obtain and communicate information describing how changes in environmental conditions can affect the distribution of traits in a population and cause increases in the numbers of some species, the emergence of new species, and the extinction of other species.**

e. **Use evidence obtained from new technologies to compare similarity in DNA sequences, anatomical structures, and embryological appearance as evidence to support multiple lines of descent in evolution.**

f. **Plan and carry out investigations to gather evidence of patterns in the relationship between natural selection and changes in the environment.** [Clarification Statement: A possible investigation could be to study fruit flies and the number or eggs, larvae, and flies that hatch in response to environmental changes such as temperature, moisture, and acidity.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.

- Evaluate various methods of collecting data (e.g., field study, experimental design, simulations) and analyze components of the design in terms of various aspects of the study. Decide types, how much, and accuracy of data needed to produce reliable measurement and consider any limitations on the precision of the data (e.g., number of trials, cost, risk, time). (f)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. (c)
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. (c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (b)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (b)
- Base casual explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (d),(e)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (d),(e)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Genetic information, like the fossil record, also provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (e)

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (a),(c)
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (b),(c),(d),(f)

LS4.C: Adaptation

- Natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (a)
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (b),(c),(f)
- Adaptation also means that the distribution of traits in a population can change when conditions change. (d)
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (d)
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (d)

Crosscutting Concepts

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. (c),(e),(f)

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b),(d)

HS.LS-NSE Natural Selection and Evolution *(continued)*
Connections to other topics in this grade-level: **HS.ESS-HE, HS.ESS-CC**
Articulation across grade-levels: **MS.LS-NSA, MS.LS-GDRO**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.9-10.1** Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text. **RI.9-10-8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient identify false statements and fallacious reasoning. **SL.9-10.2** Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. *Mathematics –* **MP.3** Construct viable arguments and critique the reasoning of others. **N-Q** Reason quantitatively and use units to solve problems **S.ID** Summarize, represent, and interpret data on a single count or measurement variable **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.LS-IVT Inheritance and Variation of Traits

HS.LS-IVT Inheritance and Variation of Traits

Students who demonstrate understanding can:

a. Ask questions and obtain information about the role of patterns of gene sequences in DNA molecules and subsequent inheritance of traits.

b. Use a model to explain how mitotic cell division results in daughter cells with identical patterns of genetic materials essential for growth and repair of multicellular organisms. [Assessment Boundary: The focus is on conceptual understanding of the process; the details of the individual steps are beyond the intent.]

c. Construct an explanation for how cell differentiation is the result of activation or inactivation of specific genes as well as small differences in the immediate environment of the cells. [Assessment Boundary: Limited to the concept that a single cell develops into a variety of differentiated cells and thus, a complex organism.]

d. Use a model to describe the role of cellular division and differentiation to produce and maintain complex organisms composed of organ systems and tissue subsystems that work together to meet the needs of the entire organism. [Clarification Statement: The focus is on the conceptual understanding that a single cell can give rise to complex, multicellular organisms consisting of many different cells with identical genetic material.] [Assessment Boundary: Limited to the concept that a single cell develops into a variety of differentiated cells and thus, a complex organism.]

e. Communicate information about the role of the structure of DNA and the mechanisms in meiosis for transmitting genetic information from parents to offspring. [Assessment Boundary: The focus is on conceptual understanding of the process; details of the individual steps of the process of meiosis are beyond the intent.]

f. Communicate information that inheritable genetic variations may result from: (1) genetic combinations in haploid sex cells, (2) errors occurring during replication, (3) crossover between homologous chromosomes during meiosis, and (4) environmental factors. [Clarification Statement: Information on genetic variation should include evidence of understanding the probability of variations and the rarity of mutations.] [Assessment Boundary: The focus is on conceptual understanding of the sources of genetic variation that are heritable.]

g. Use probability to explain the variation and distribution of expressed traits in a population. [Assessment Boundary: Hardy-Weinberg calculations are beyond the intent of this standard.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9-12 builds from grades K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that arise from phenomena, models, theory, or unexpected results. (a)
- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (a)

Developing and Using Models
Modeling in 9-12 builds on K-8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (b)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use statistical and mathematical techniques and structure data (e.g. displays, tables, graphs) to find regularities, patterns (e.g. fitting mathematical curves to data), and relationships in data. (g)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (c),(d)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, and theories) and peer review. (c),(d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9-12 builds on 6-8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (f)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (e),(f)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. (a),(b)
- As successive subdivisions of an embryo's cells occur, programmed genetic instructions and small differences in their immediate environments activate or inactivate different genes, which cause the cells to develop differently—a process called differentiation. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (b),(c),(d)
- In sexual reproduction, a specialized type of cell division called meiosis occurs that results in the production of sex cells, such as gametes in animals (sperm and eggs), which contain only one member from each chromosome pair in the parent cell. (e)

LS3.A: Inheritance of Traits

- In all organisms the genetic instructions for forming species' characteristics are carried in the chromosomes. (f)
- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. (a)
- All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (c),(f),(g)

LS3.B: Variation of Traits

- The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes. (a)
- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. (f)
- Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (f)
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (g)

Crosscutting Concepts

Patterns
Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. (a),(b)

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (c),(f),(g)

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (d)

Structure and Function
Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (e)

HS.LS-IVT Inheritance and Variation of Traits *(continued)*
Connections to other topics in this grade-level: **HS.LS-NSE**
Articulation across grade-levels: **MS.LS-GDRO**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **SL.1** Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions. **W.1** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **W.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. **RST.9-10.1** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. **RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. **RST.9-10.9** Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **F.BF** Build a function that models a relationship between two quantities. **A.CED** Create equations that describe numbers or relationships. **S.MD** Use probability to evaluate outcomes of decisions

MS.ESS-SS Space Systems

Students who demonstrate understanding can:

a. **Construct explanations for the occurrences of day/night cycles, seasons, tides, eclipses, and lunar phases based on patterns of the observed motions of celestial bodies.** [Assessment Boundary: Kepler's Laws of orbital motion are not used as the basis for evidence at this level.]

b. **Obtain, evaluate, and communicate information about the expansion and scale of the universe to support the Big Bang theory.** [Clarification Statement: Evidence should include qualitative discussions of the cosmic background radiation, the motions of galaxies away from each other, and the resulting prevalence of hydrogen and helium in the universe.]

c. **Construct and use models to describe the location of Earth with respect to the size and structure of the solar system, Milky Way Galaxy, and universe.** [Assessment Boundary: Mathematical models are not expected; use AU for Solar System scale; use light years for universal scale.]

d. **Use models to support explanations of the composition, structure, and formation of the solar system from a disk of dust and gas drawn together by gravity.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (c),(d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluate the merit and validity of ideas and methods.

- Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions, and competing information. (b)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (a)
- The universe began with a period of extreme and rapid expansion known as the Big Bang. Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang. (b)
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (c)

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. This system appears to have formed from a disk of dust and gas, drawn together by gravity. (d)
- This model of the solar system can explain tides, eclipses of the sun and the moon, and the apparent motions of the planets in the sky relative to the stars. (a)
- Earth's spin axis is fixed in direction (in the short-term) but tilted relative to its orbit around the sun; the differential intensity of sunlight on different areas of Earth over the year is a result of that tilt, as are the seasons that result. (a)

PS2.C: Stability and Instability in Physical Systems

- A system can be changing but have a stable repeating cycle of changes; such observed regular patterns allow predictions about the system's future (e.g., Earth orbiting the sun). (a)

Crosscutting Concepts

Patterns

Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a),(d)

Scale, Proportion, and Quantity

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (b)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (c)

Connections to other DCIs in this grade-level: **MS.LS-GDRO, MS.PS-FM, MS.PS-IF, MS.PS-E**

Articulation to DCIs across grade-levels: **1.PC, 5.SSS, HS.ESS-SS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.
W.6.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
W.7.1 Write arguments to support claims with clear reasons and relevant evidence.
W.7.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1 Write arguments to support claims with clear reasons and relevant evidence.
W.8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.4 Model with mathematics
8.F Use functions to model relationships between quantities

MS.ESS-HE The History of Earth

MS.ESS-HE The History of Earth

Students who demonstrate understanding can:

a. **Construct explanations for patterns in geologic evidence to determine the relative ages of a sequence of events that have occurred in Earth's past.** [Clarification Statement: Evidence can be field evidence or representations (e.g., model of geologic cross-sections). Events may include sedimentary layering, fossilization, folding, faulting, igneous intrusion, and/or erosion.]

b. **Use models of the geologic time scale in order to organize major events in Earth's history.** [Clarification Statement: Models may be temporal (e.g., clock) or spatial (e.g., football field).] [Assessment Boundary: Memorization of specific periods or epochs of the geologic timescale is not intended.]

c. **Construct explanations from evidence for how different geologic processes shape Earth's evolution over widely varying scales of space and time.** [Clarification Statement: Chemical erosion of a mountain occurs at molecular scales while mountain building can occur through large-scale tectonic processes; meteor impacts are nearly instantaneous, mountain building can take many millions of years. It is appropriate to use regional geographical features familiar to students.]

d. **Use empirical evidence from the rock and fossil records to investigate how past geologic events have caused major extinctions of life forms on Earth and how these extinctions have subsequently allowed other life forms to flourish.**

e. **Use models of the geosphere and biosphere that highlight system interactions to explain how the geosphere and biosphere coevolve over geologic time.** [Assessment Boundary: Use examples of weathering and erosion of land surfaces, composition of soils and atmosphere, and distribution of water in the hydrosphere.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (b),(e)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis (a possible explanation that predicts a particular and stable outcome) based on a model or theory. (d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a)
- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (c)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth
- The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Major historical events include the formation of mountain chains and ocean basins, evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and the development of watersheds and rivers through glaciation and water erosion. (b)
- Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (a)

ESS2.A: Earth's Materials and Systems
- Earth's systems interact over scales that range from microscopic to global in size, and operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (c)

ESS2.E: Biogeology
- The evolution of life is shaped by Earth's varying geologic conditions. Sudden changes in these conditions (e.g., meteor impacts or major volcanic eruptions) have caused mass extinctions in Earth's past. However, these changes, as well as more gradual ones, have also allowed other existing or new life forms to flourish. (d)
- Organisms continually evolve to new and often more complex forms as they adapt to new environments. (e)
- The evolution and proliferation of living things over geologic time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere. (e)

Crosscutting Concepts

Scale, Proportion, and Quantity
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (a)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (b)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (c),(d),(e)

Connections to other DCIs in this grade-level: **MS.LS-NSA, MS.LS-IRE**

Articulation to DCIs across grade-levels: **K.OTE, 2.IOS, 2.ECS, 4.PSE, HS.ESS-HE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
W.6.1 Write arguments to support claims with clear reasons and relevant evidence.
W.6.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
SL.6.3 Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.
W.7.1 Write arguments to support claims with clear reasons and relevant evidence.
W.7.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.7.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.
SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1 Write arguments to support claims with clear reasons and relevant evidence.
W.8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.8.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.
SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3 Reason abstractly and quantitatively
MP.4 Model with mathematics.
8.F Use functions to model relationships between quantities
8.SP Investigate patterns of association in biivariate data

MS.ESS-EIP Earth's Interior Processes

MS.ESS-EIP Earth's Interior Processes

Students who demonstrate understanding can:

a. **Use models to explain how the flow of energy drives a cycling of matter between Earth's surface and deep interior.** [Assessment Boundary: The thermodynamic processes that drive convection are not required, only a description of those motions. Explanations should include mid-ocean ridges and ocean trenches.]

b. **Develop and use models of ancient land and ocean basin patterns to explain past plate motions.** [Assessment Boundary: Explanations should be based on fossil evidence, evidence from rock formations, continent shapes, and seafloor structures.]

c. **Use representations of current plate motions, based on data from modern techniques like GPS, to predict future continent locations.** [Clarification Statement: Representations may include maps.]

d. **Plan and carry out investigations that demonstrate the chemical and physical processes that form rocks and cycle Earth materials.** [Assessment Boundary: Students should use various materials to replicate, simulate, and demonstrate the processes of crystallization, heating and cooling, weathering, deformation, and sedimentation involved. Investigations should focus on connecting, correlating, and identifying parts of the rock cycle.]

e. **Construct explanations for how the uneven distribution of Earth's mineral and energy resources, which are limited and often non-renewable, are a result of past and current geologic processes, including plate motions.**

f. **Analyze and interpret data sets to describe the history of natural hazards in a region to identify the patterns of hazards that allow for forecasts of the locations and likelihood of future events.** [Assessment Boundary: Hazards are limited to those resulting from Earth's interior processes (e.g., volcanoes, earthquakes, tsunamis).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a),(b),(c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (d)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships
- Distinguish between causal and correlational relationships. (f)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (e)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth
- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (a)

ESS2.A: Earth Materials and Systems
- Earth's internal processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from Earth's hot interior. The flow of energy and cycling of matter produce chemical and physical changes in Earth's interior materials and living organisms. (a)
- Solid rocks can be formed by the cooling of molten rock, the accumulation and consolidation of sediments, or the alteration of older rocks by heat, pressure, and fluids. (d)

ESS2.B: Plate Tectonics and Large-Scale System Interactions
- The top part of the mantle, along with the crust, forms structures known as tectonic plates. (b),(c)
- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (b)

ESS3.A: Natural Resources
- Humans depend on Earth's interior for many different resources. Mineral and energy resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (e)

ESS3.B: Natural Hazards
- Some natural hazards, such as volcanic eruptions, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. However, mapping the history of natural hazards in a region and developing an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (f)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (b),(c),(d)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (a),(e)

- -

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology, on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (f)

Connections to other DCIs in this grade-level: **MS.ESS-ESP, MS.PS-IF, MS.PS-E, MS.PS-CR, MS.PS-SPM**

Articulation to DCIs across grade-levels: **K.WEA, 2.ECS, 3.WCI, 4.PSE, 5.ESI, HS.ESS-ES, HS.ESS-HS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

W.8.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3 Reason abstractly and quantitatively

MP.4 Model with mathematics.

8.F Use functions to model relationships between quantities

8.SP Investigate patterns of association in bivariate data

MS.ESS-ESP Earth's Surface Processes

MS.ESS-ESP Earth's Surface Processes

Students who demonstrate understanding can:

a. Use models to explain how weathering, erosion, and deposition of Earth materials, by the movement of water, shape landscapes and create underground formations. [Clarification Statement: Models may include maps.]

b. Model multiple pathways for the cycling of water through the atmosphere, geosphere, and hydrosphere as it changes phase and moves in response to energy from the sun and the force of gravity. [Assessment Boundary: Heat of vaporization and heat of condensation are not to be addressed.]

c. Plan and conduct investigations to explain how temperature and salinity cause changes in density which affect the separation and movement of water masses within the ocean. [Assessment Boundary: Complex system interactions such as the Coriolis Effect are not required.]

d. Plan and carry out investigations of the variables that affect how water causes the erosion, transportation, and deposition of surface and subsurface materials as evidence of how matter cycles through Earth's systems.

e. Apply scientific knowledge to design engineered solutions to natural hazards that result from surface geologic and hydrologic processes. [Clarification Statement: Examples of natural hazards are flooding, avalanches, and landslides. Direct methods engineers use to control flooding include building artificial levees and dams.]

f. Generate and revise causal explanations for how physical and chemical interactions among rocks, sediments, water, air, and organisms contribute to the weathering and erosion of rocks and the formation of soil.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a),(b)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables, and controls. (c)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (f)
- Apply scientific knowledge to explain real-world examples or events and solve design problems. (e)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems
- Earth's surface processes are the result of energy flowing and matter cycling within and among the planet's surface systems. This energy is derived from electromagnetic radiation from the sun. This flow of energy and cycling of matter produce chemical and physical changes in Earth's surface materials and living organisms. (b),(d)
- Physical and chemical interactions among rocks, sediments, water, air, and plants and animals produce soil. (f)

ESS2.C: The Roles of Water in Earth's Surface Processes
- Water continually cycles among the land, ocean, and atmosphere via transpiration, evaporation, condensation, precipitation, and the downhill runoff on land. Global movements of water and changes in its chemical phase are driven by sunlight and gravity. (b)
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (c)
- Water's movements both on the land and underground cause weathering and erosion, which change the land's surface features and create underground formations. (a)

ESS3.B: Natural Hazards
- Surface-related geologic processes create natural resources needed by humans and cause natural hazards that pose challenges to human society (e.g., landslides, coastal erosion). (e)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (c),(d),(f)

Systems and System Models
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (a),(b)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (e)

Connections to other DCIs in this grade-level: **MS.ESS-EIP, MS.LS-MEOE MS.PS-IF, MS.PS-E, MS.PS-CR, MS.PS-WER, MS.PS-SPM**

Articulation to DCIs across grade-levels: **K.WEA, 3.WCI, 4.PSE, 5.ESI, HS.ESS-ES, HS.ESS-HS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

WHST.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
W.6.1	Write arguments to support claims with clear reasons and relevant evidence.
W.7.1	Write arguments to support claims with clear reasons and relevant evidence.
SL.7.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1	Write arguments to support claims with clear reasons and relevant evidence.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3	Reason abstractly and quantitatively
MP.4	Model with mathematics.
7.RP	Analyze proportional relationships and use them to solve real-world and mathematical problems
8.F	Use functions to model relationships between quantities

MS.ESS-WC Weather and Climate Systems

MS.ESS-WC Weather and Climate Systems

Students who demonstrate understanding can:

a. **Generate and revise causal explanations given specific temperature and precipitation data sets at different geographic locations to answer questions about interactions that influence weather.** [Clarification Statement: Factors that interact and influence weather should include sunlight, ocean, atmosphere, ice, landforms and living things.] [Assessment Boundary: Students consider interactions between only two variables at a time.]

b. **Construct models to describe and explain how circulation in the atmosphere and ocean results from unequal heating of Earth's surface and is influenced by latitude, altitude, geography, and Earth's rotation.** [Clarification Statement: Atmospheric and oceanic circulation may include Hadley cells, the Gulf Stream, and the prevailing westerlies and trade winds.] [Assessment Boundary: Students do not need to explain the mechanism causing the Coriolis effect.]

c. **Use mathematics to analyze weather data and forecasts to identify patterns and variations that cause weather forecasts to be issued in terms of probabilities.** [Clarification Statement: Averages and basic probability should be used to analyze weather data.]

d. **Construct explanations, from models of oceanic and atmospheric circulation, for the development of local and regional climates.** [Assessment Boundary: Students should construct explanations for their own local climate.]

e. **Use models of Earth's atmosphere and surface to explain how energy from the sun is absorbed and retained by various greenhouse gases in Earth's atmosphere, thereby regulating Earth's average surface temperature and keeping Earth habitable.** [Assessment Boundary: Explanations should include an understanding that energy can take different forms and can be tracked as it moves through Earth's systems. Students do not have to explain the differing wavelengths of radiation received and reemitted from Earth's surface. Amount of energy absorbed by different reservoirs is not assessed at this level.]

f. **Construct a model to track and explain the inputs, outputs, pathways, and storage of carbon among the geosphere, biosphere, hydrosphere, and atmosphere.** [Assessment Boundary: Details of biogeochemical reactions involving carbon and actual amounts of reactants and products are not assessed at this level.]

g. **Use argumentation to evaluate the competing demands for various human uses of fresh water and biosphere resources.** [Assessment Boundary: Arguments should take into account the uneven distribution of the resources and the natural limits to their availability.]

h. **Use maps and other visualizations to analyze large data sets that illustrate the frequency, magnitude, and resulting damage from severe weather events in order to assess the likelihood and severity of future events.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (b),(e),(f)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigation, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships. (h)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Use mathematical concepts such as ratios, averages, basic probability, and simple functions, including linear relationships, to analyze data. (c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a)
- Construct explanations from models or representations. (d)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (g)

Disciplinary Core Ideas

ESS2.C: The Roles of Water in Earth's Surface Processes
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (a),(b),(d)

ESS2.D: Weather and Climate
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (a),(b)
- Because these patterns are so complex, weather can only be predicted probabilistically. (c),(e)
- The ocean and land exert major influences on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it via oceanic and atmospheric circulation. The patterns of differential heating, together with Earth's rotation and the configuration of continents and oceans, control the large-scale patterns of oceanic and atmospheric circulation. (a),(b),(d)
- Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping Earth habitable. (e)

ESS2.E: Biogeology
- Organisms ranging from bacteria to human beings are a major driver of the global carbon cycle, and they influence global climate by modifying the chemical makeup of the atmosphere. (e),(f)

ESS3.A: Natural Resources
- Humans depend on Earth's ocean, atmosphere, and biosphere for many different resources. Fresh water and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of weather-and climate-related processes. (g)

ESS3.B: Natural Hazards
- Severe weather events (e.g., hurricanes, floods, forest fires) are often preceded by observable phenomena that allow for reliable predictions. Constant monitoring of weather hazards in a region and the development of an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (h)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(b),(c),(d),(h)

Energy and Matter
Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (e),(f)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (g)

MS.ESS-WC Weather and Climate Systems

MS.ESS-WC Weather and Climate Systems	
Connections to other DCIs in this grade-level: **MS.LS-MEOE, MS.PS-IF, MS.PS-E, MS.PS-WER**	
Articulation to DCIs across grade-levels: **K.WEA, 3.WCL, 4.PSE, 4.E, HS.ESS-CC, HS.ESS-HS**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
WHST.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
W.6.1	Write arguments to support claims with clear reasons and relevant evidence.
W.7.1	Write arguments to support claims with clear reasons and relevant evidence.
SL.7.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1	Write arguments to support claims with clear reasons and relevant evidence.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
Mathematics –	
MP.3	Reason abstractly and quantitatively
MP.4	Model with mathematics.
7.RP	Analyze proportional relationships and use them to solve real-world and mathematical problems

MS.ESS-HI Human Impacts

MS.ESS-HI Human Impacts

Students who demonstrate understanding can:

a. **Use system models and representations to explain how human activities significantly impact: (1) the geosphere, (2) the hydrosphere, (3) the atmosphere, (4) the biosphere, and (5) global temperatures.** [Clarifying Statement: System models and representations include diagrams, charts, and maps. Examples of human impact are changes in land use and resource development (geosphere); water pollution and urbanization (hydrosphere); air pollution in the form of gases, aerosols, and particulates (atmosphere); changes to natural environments (biosphere); release of greenhouse gases (global temperatures).]

b. **Generate and revise qualitative explanations from data for the impacts on Earth's systems that result from increases in human population and rates of consumption.** [Assessment Boundary: Students should be provided with modified regional databases on human populations and rates of consumption. "Impacts" include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change.]

c. **Design engineering solutions for stabilizing changes to communities by: (1) using water efficiently, (2) minimizing human impacts on environments and local landscapes by reducing pollution, and (3) reducing the release of greenhouse gases.**

d. **Ask questions to refine and develop an explanation for the way technological monitoring of Earth's systems can provide the means of informing the public of ways to modify human impacts on Earth's systems.**

e. **Use empirical evidence to evaluate technologies that utilize renewable energy resources.** [Assessment Boundary: Students will evaluate these technologies based on their cost, benefit, sustainability, and environmental impacts.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.

- Ask questions to refine a model, an explanation, or an engineering problem. (d)

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (b)
- Apply scientific knowledge to explain real-world examples or events and solve design problems. (c)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (e)

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems

- Humans have become one of the most significant agents of change in the near-surface Earth system. Human activities have significantly altered the biosphere, geosphere, hydrosphere, and atmosphere. (a)
- As human populations and per-capita consumption of natural resources increase, so do the impacts on Earth's systems unless the activities and technologies involved are engineered otherwise. (b),(c)
- Continued monitoring of the changes to Earth's surface provides a deeper understanding of the way in which human activities are impacting Earth's systems, providing the basis for social policies and regulations that can reduce these impacts. (d)

ESS3.D: Global Climate Change

- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature ("global warming"). (a)
- Reducing the amount of greenhouse gases released into the atmosphere can reduce the degree to which global temperatures will increase. (c)
- Renewable energy resources and the technologies to exploit them are being rapidly developed. (e)

Crosscutting Concepts

Systems and System Models

Systems may interact with other systems; they may have sub-systems and be part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (a)

Stability and Change

Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (c)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward. (d)

Influence of Science, Engineering, and Technology on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (b),(e)

Connections to other DCIs in this grade-level: **MS.LS-NSA, MS.LS-IRE, MS.PS-E, MS.PS-WER, MS.PS-SPM**

Articulation to DCIs across grade-levels: **K.OTE, 5.ESI, HS.ESS-CC, HS.ESS-HS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

W.8.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3 Reason abstractly and quantitatively

MP.4 Model with mathematics

7.SP Use random sampling to draw inferences about a population; Draw informal comparative inferences about two populations

HS.ESS-SS Space Systems

HS.ESS-SS Space Systems

Students who demonstrate understanding can:

- **a. Construct explanations from evidence about how the stability and structure of the sun change over its lifetime at time scales that are short (solar flares), medium (the hot spot cycle), and long (changes over its 10-billion-year lifetime).** [Clarification Statement: Evidence for long-term changes includes the Hertzsprung-Russell Diagram.]
- **b. Use mathematical, graphical, or computational models to represent the distribution and patterns of galaxies and galaxy clusters in the Universe to describe the Sun's place in space.**
- **c. Construct explanations for how the Big Bang theory accounts for all observable astronomical data including the red shift of starlight from galaxies, cosmic microwave background, and composition of stars and nonstellar gases.**
- **d. Obtain, evaluate, and communicate information about the process by which stars produce all elements except those elements formed during the Big Bang.** [Clarification Statement: Nuclear fusion within certain stars produce atomic nuclei lighter than and including iron; heavier elements are produced when certain massive stars achieve a supernova stage and explode.]
- **e. Use mathematical representations of the positions of objects in the Solar System to predict their motions and gravitational effects on each other.** [Assessment Boundary: Mathematical representations, which include Kepler's Laws, should not deal with more than 2 bodies.]
- **f. Analyze evidence to show how changes in Earth's orbital parameters affect the intensity and distribution of sunlight on Earth's surface, causing cyclical climate changes that include past Ice Ages.** [Assessment Boundary: Orbital parameters are limited to change in orbital shape and orientation of the planetary axis.]
- **g. Construct explanations for how differences in orbital parameters, combined with the object's size and composition, control the surface conditions of other planets and moons within the solar system.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (f)

Using Mathematical and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use statistical and mathematical techniques and structure data (e.g., displays, tables, graphs) to find regularities, patterns (e.g., fitting mathematical curves to data), and relationships in data. (b)
- Use simple limit cases to test mathematical expressions, computer programs or algorithms, or simulations to see if a model "makes sense" by comparing the outcomes with what is known about the real world. (e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (a),(c),(g)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (d)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (a)
- The sun is one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. (b)
- The spectra and brightness of stars are used to identify their compositional elements, movements, and distances from Earth and to develop explanations about the formation, age, and composition of the universe. The Big Bang theory is supported by the fact that it provides an explanation of observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (c)
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (c),(d)

ESS1.B: Earth and the Solar System

- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (e)
- Cyclic changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, have altered the intensity and distribution of sunlight falling on Earth. These changes, both occurring over tens to hundreds of thousands of years, cause cycles of ice ages and other gradual climate changes. (f),(g)

Crosscutting Concepts

Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (b)

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (e),(g)

Energy and Matter

The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (a),(c),(d),(f)

HS.ESS-SS Space Systems

HS.ESS-SS Space Systems	
Connections to other DCIs in this grade-level: **HS.PS-NP, HS.PS-ER, HS.PS-E, HS.PS-FM, HS.PS-FE, HS.PS-IF**	
Articulation to DCIs across grade-levels: **1.PC, 5.SSS, MS.ESS-SS**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
RI.9-10.1	Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
W.9-10.9(b)	Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
W.11-12.9(b)	Draw evidence from literary or informational texts to support analysis, reflection, and research.
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with mathematics
MP.5	Use appropriate tools strategically
S.ID	Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies
G.MG	Apply geometric concepts in modeling situations
F.IF	Interpret functions that arise in applications in terms of the context
F.BF	Build a function that models a relationship between two quantities
F.LE	Construct and compare linear, quadratic, and exponential models and solve problems

HS.ESS-HE History of Earth

HS.ESS-HE History of Earth

Students who demonstrate understanding can:

a. Analyze determined or hypothetical isotope ratios within Earth materials to make valid and reliable scientific claims about the planet's age, the ages of Earth events and rocks, and the overall time scale of Earth's history. [Assessment Boundary: Radiometric dating techniques using complex methods such as multiple isotope ratios are not included.]

b. Construct an explanation, using plate tectonic theory, for the general trends of the ages of continental and oceanic crust and the patterns of topographic features. [Clarification Statement: Trends of crustal ages involve the youngest seafloor rocks located at mid-ocean ridges and the oldest ocean rocks often located near continental boundaries, with age bands of rocks parallel across mid-ocean ridges. Major topographic features are ocean ridges, trenches, and hot spot islands.]

c. Construct explanations about changes that occurred to Earth during the Hadean Eon based on data from Earth materials, planetary surfaces, and meteorites. [Clarification Statement: Dynamic Earth processes have destroyed most of Earth's very early rock record; however, lunar rocks, asteroids, and meteorites have remained relatively unchanged and provide evidence for conditions during Earth's earliest time periods.]

d. Construct scientific arguments to support the claim that dynamic causes, effects, and feedbacks among Earth's systems result in a continual coevolution of Earth and the life that exists on it. [Assessment Boundary: Students examine examples of feedbacks between Earth's different systems to understand how life has coevolved with Earth's surface (e.g., the atmosphere and biosphere affect the conditions for life, which in turn affects the composition of the atmosphere.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (b),(c)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth

- Radioactive-decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geologic time. (a)
- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (b)
- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (c)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (b)
- Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (b)

ESS2.E Biogeology

- The many dynamic and delicate feedbacks among the biosphere, geosphere, hydrosphere, and atmosphere cause a continual co-evolution of Earth's surface and the life that exists on it. (d)

Crosscutting Concepts

Scale, Proportion, and Quantity
Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g. linear growth vs. exponential growth). (a)

Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (b),(c),(d)

Connections to other DCIs in this grade-level: **HS.LS-IVT, HS.LS-NSE, HS.LS-MEOE, HS.LS-IRE, HS.PS-SPM, HS.PS-NP, HS.PS-CR, HS.PS-E**

Articulation to DCIs across grade-levels: **K.OTE, 2.IOS, 2.ECS, 4.PSE, MS.ESS-HE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.9-10.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.9-10.1	Write arguments focused on discipline-specific content.
W.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
W.11-12.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.11-12.1	Write arguments focused on discipline-specific content.
W.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

Mathematics –

MP.2	Reason abstractly and quantitatively
MP.3	Construct viable arguments and critique the reasoning of others.
MP.5	Use appropriate tools strategically
S.ID	Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.ESS-ES Earth's Systems

HS.ESS-ES Earth's Systems

Students who demonstrate understanding can:

a. Apply scientific reasoning to explain how geophysical, geochemical, and geothermal evidence was used to develop the current model of Earth's interior. [Clarification Statement: Evidence should include drill cores, gravity, seismic waves, and laboratory experiments on Earth materials.]

b. Use a model of Earth's interior and the mechanisms of thermal convection to explain the cycling of matter and the impact of plate tectonics on Earth's surface. [Assessment Boundary: Convection mechanisms should include heat from radioactive decay and gravity acting on materials of different densities as the drivers of convection and tectonic activity.]

c. Analyze the impact of water on the flow of energy and the cycling of matter within and among Earth systems. [Assessment Boundary: Should explore the unique physical and chemical properties of water, such as the polar nature of the molecule and water's ability to absorb/store/release energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.]

d. Use Earth system models to explain how Earth's internal and surface processes work together at different spatial and temporal scales to form landscapes and sea floor features.

e. Construct an evidence-based claim about how a change to one part of an Earth system creates feedbacks that causes changes in other systems (e.g., coastal dynamics, watersheds and reservoirs, stream flow and erosion rates, changes in ecosystems).

f. Use mathematical expressions of phenomena to simulate how temperature, relative humidity, air pressure, and the dew point vary from the windward to the leeward side of a mountain range. [Clarification Statement: The phenomena include latent heat, adiabatic heating/cooling, absolute/relative humidity, and dew point.]

g. Use models to analyze data to make claims about how energy from the sun is redistributed throughout the atmosphere. [Clarification Statement: Unequal heating of the atmosphere results in high and low pressure systems; air moves from areas of high pressure to low pressure; clockwise and counter-clockwise atmospheric circulations develop in response to Earth's rotation (the Coriolis Effect).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (b),(d),(g)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (f)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (a)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems
- Evidence from drill cores, gravity, seismic waves, and laboratory experiments on Earth materials, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of geophysical and geochemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. (a)
- Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and the increased downward gravitational pull on denser mantle material. (b)
- Earth's systems interact over a wide range of temporal and spatial scales and continually react to changing influences, including those from human activities. Components of Earth's systems may appear stable, change slowly over long periods of time, or change abruptly. Changes in part of one system can cause dynamic feedbacks that can increase or decrease the original changes, further changing that system or other systems in ways that are often surprising and complex. (d),(e)
- Weather is driven by interactions of the geosphere, hydrosphere, and atmosphere. (f),(g)

ESS2.B: Plate Tectonics and Large-Scale System Interactions
- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (b)

ESS2.C: The Roles of Water in Earth's Surface Processes
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb/store/release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (c)

Crosscutting Concepts

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (a)

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (d),(e)

Energy and Matter
The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (b),(c),(f),(g)

HS.ESS-ES Earth's Systems

HS.ESS-ES Earth's Systems
Connections to other DCIs in this grade-level: **HS.LS-MEOE, HS.LS-IRE, HS.PS-SPM, HS.PS-CR, HS.PS-ER, HS.PS-E, HS.PS-FM, HS.PS-FE, HS.PS-IF**
Articulation to DCIs across grade-levels: **K.OTE, K.WEA, 2.IOS, 2.ECS, 3.WCI, 4.PSE, 5.ESI, MS.ESS-EIP, MS.ESS-ESP**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **W.9-10.1** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **W.9-10.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. **W.11-12.1** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **W.11-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. *Mathematics –* **MP.2** Reason abstractly and quantitatively **MP.4** Model with mathematics **MP.5** Use appropriate tools strategically **S.ID** Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.ESS-CC Climate Change

HS.ESS-CC Climate Change

Students who demonstrate understanding can:

a. Evaluate and communicate the climate changes that can occur when certain components of the climate system are altered. [Clarification Statement: For example, evaluate variations in incoming solar radiation as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems.]

b. Construct a scientific argument showing that changes to any one of many different Earth and Solar System processes can affect global and regional climates. [Clarification Statement: Examples of these processes include the sun's energy output, Earth's orbit and axis orientation, tectonic events, ocean circulation, volcanic activity, glacial activity, the biosphere, and human activities.] [Assessment Boundary: Use evidence from the geologic record only.]

c. Analyze geologic evidence that past climate changes have occurred over a wide range of time scales. [Clarification Statement: Examples of evidence are ice core data, the fossil record, sea level fluctuations, glacial features.]

d. Engage in critical reading of scientific literature about causes of climate change over 10s-100s of years, 10s-100s of thousands of years, or 10s-100s of millions of years. [Clarification Statement: Examples of causes are changes in solar output, ocean circulation, volcanic activity (10s-100s of years); changes to Earth's orbit and the orientation of its axis (10s-100s of thousands of years); or long-term changes in atmospheric composition (10s-100s of millions of years).]

e. Use global climate models in combination with other geologic data to predict and explain how human activities and natural phenomena affect climate, providing the scientific basis for planning for humanity's future needs. [Clarification Statement: For example, use global climate models together with topographic maps to investigate effects of sea level change or combine global climate models with precipitation maps to investigate locations where new water supplies will be needed.]

f. Apply scientific knowledge to investigate how humans may predict and modify their impacts on future global climate systems (e.g., investigating the feasibility of geoengineering design solutions to global temperature changes).

g. Use models of the flow of energy between the sun and Earth's atmosphere and surface to explain how different wavelengths of energy are absorbed and retained by various greenhouse gases in Earth's atmosphere, thereby affecting Earth's radiative balance. [Clarification Statement: Students will work with absorption spectra of different Earth materials.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena, and move flexibly between model types based on merits and limitations. (g)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (e)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (f)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (b)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (a),(d)

Disciplinary Core Ideas

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. Climate change can occur when certain parts of these systems are altered. (a)
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (b),(c),(d)
- Geologic evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer-term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more graduate atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate (link to ESS3.D). (b),(c),(d)
- Global climate models are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. Global climate models incorporate scientists' best knowledge of the physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations. (e)
- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. Hence the outcomes depend on human behaviors (link to ESS3.D) as well as on natural factors that involve complex feedbacks among Earth's systems (link to ESS3.A). (f)

ESS3.D: Global Climate Change

- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (g)
- Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences–for humanity as well as for the rest of the planet. (g)

Crosscutting Concepts

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (e),(g)

Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (a),(b),(c),(d)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (f)

HS.ESS-CC Climate Change

HS.ESS-CC Climate Change

Connections to other DCIs in this grade-level: **HS.LS-MEOE, HS.LS-IRE, HS.PS-ER, HS.PS-W, HS.PS-E**

Articulation to DCIs across grade-levels: **K.WEA, K.OTE, 3.WCI, 5.ESI, MS.ESS-WC, MS.ESS-HI**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.9-10.9(b) Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.9-10.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.9-10.1 Write arguments focused on discipline-specific content.
SL.9-10.1.c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
W.11-12.9(b) Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.11-12.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.11-12.1 Write arguments focused on discipline-specific content.
SL.11-12.1.c Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

Mathematics –

MP.2 Reason abstractly and quantitatively
MP.3 Construct viable arguments and critique the reasoning of others
MP.4 Model with mathematics
S.ID Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
F.LE Construct and compare linear, quadratic, and exponential models and solve problems
S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.ESS-HS Human Sustainability

HS.ESS-HS Human Sustainability

Students who demonstrate understanding can:

- **a. Construct arguments for how the developments of human societies have been influenced by natural resource availability including: locations of streams, deltas, and high concentrations of minerals, ores, coal, and hydrocarbons.**
- **b. Reflect on and revise design solutions for local resource development that would increase the ratio of benefits to costs and risks to the community and its environment.** [Clarification Statement: Examples of local resource development include soil use for agriculture, water use, mining for coal and minerals, pumping for oil and natural gas.]
- **c. Construct scientific claims for how increases in the value of water, mineral, and fossil fuel resources due to increases in population and rates of consumption have sometimes led to the development of new technologies to retrieve resources previously thought to be economically or technologically unattainable.**
- **d. Construct scientific arguments from evidence to support claims that natural hazards and other geologic events have influenced the course of human history.** [Clarification Statement: Famines that result from reduced global temperatures can follow large historic volcanic eruptions. Large earthquakes and tsunamis can destroy cities, and there is a strong correlation between historic climate changes and the number of wars.]
- **e. Construct scientific claims about the impacts of human activities on the frequency and intensity of some natural hazards.** [Clarification Statement: Natural hazards to include floods, droughts, forest fires, landslides, etc.]
- **f. Identify mathematical relationships using data on the rates of production and consumption of natural resources in order to assess the global sustainability of human society.** [Assessment Boundary: Students construct equations for linear relationships, but not expected to construct equations for non-linear relationships.]
- **g. Construct arguments about how engineering solutions have been and could be designed and implemented to mitigate local or global environmental impacts.** [Clarification Statement: Environmental impacts to include acid rain, water pollution, the ozone hole, etc.]
- **h. Use results from computational General Circulation Models (GCMs) to investigate how the hydrosphere, atmosphere, geosphere, and biosphere are being modified in response to human activities.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (h)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Students also use and create simple computational simulations based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (f)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (c),(d),(e),(g)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (a)
- Criticize and evaluate arguments and design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (b)

Disciplinary Core Ideas

ESS3.A: Natural Resources

- Resource availability has guided the development of human society. Resource availability affects geopolitical relationships and can limit development. (a)
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (b)
- As the global human population increases and people's demands for better living conditions increase, resources considered readily available in the past, such as land for agriculture or drinkable water, are becoming scarcer and more valued. (c)

ESS3.B: Natural Hazards

- Natural hazards and other geologic events have shaped the course of human history by destroying buildings and cities, eroding land, changing the courses of rivers, and reducing the amount of arable land. These events have significantly altered the sizes of human populations and have driven human migrations. (d)
- Natural hazards can be local, regional, or global in origin, and their risks increase as populations grow. Human activities can contribute to the frequency and intensity of some natural hazards. (e)

ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (f)
- Scientists and engineers can make major contributions–for example, by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. When the source of an environmental problem is understood and international agreement can be reached, human activities can be regulated to mitigate global impacts (e.g., acid rain and the ozone hole over Antarctica). (g)
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities and changes in human activities. (h)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (d),(h)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (c)

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (a),(b),(e),(f),(g)

HS.ESS-HS Human Sustainability

HS.ESS-HS Human Sustainability
Connections to other DCIs in this grade-level: **HS.LS-IRE, HS.PS-CR, HS.PS-E, HS.ETS-ETSS**
Articulation to DCIs across grade-levels: **K.WEA, 3.WCI, 4.PSE, 4.E, MS.ESS-WC, MS.ESS-EIP, MS.ESS-ESP, MS.ESS-HI**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **W.9-10.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **W.9-10.1** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **W.9-10.4** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. **WHST.9-10.1** Write arguments focused on discipline-specific content. **W.11-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data **W.11-12.1** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **W.11-12.4** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. **WHST.11-12.1** Write arguments focused on discipline-specific content. *Mathematics –* **MP.2** Reason abstractly and quantitatively **MP.3** Construct viable arguments and critique the reasoning of others **MP.4** Model with mathematics **F.IF** Interpret functions that arise in applications in terms of the context **F.BF** Build a function that models a relationship between two quantities **F.LE** Construct and compare linear, quadratic, and exponential models and solve problems **G.MG** Apply geometric concepts in modeling situations **A-CED.1** Create equations that describe numbers or relationships **S.ID** Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

MS.PS-SPM Structure and Properties of Matter

MS.PS-SPM Structure and Properties of Matter

Students who demonstrate understanding can:

a. Construct and use models to explain that atoms combine to form new substances of varying complexity in terms of the number of atoms and repeating subunits. [Clarification Statement: Examples of atoms combining can include Hydrogen (H_2) and Oxygen (O_2) combining to form hydrogen peroxide (H_2O_2) or water (H_2O).] [Assessment Boundary: Valence electrons and bonding energy are not addressed.]

b. Plan investigations to generate evidence supporting the claim that one pure substance can be distinguished from another based on characteristic properties. [Clarification Statement: Properties of substances can include melting and boiling points, density, solubility, reactivity, flammability, and phase.]

c. Use a simulation or mechanical model to determine the effect on the temperature and motion of atoms and molecules of different substances when thermal energy is added to or removed from the substance. [Assessment Boundary: Quantification of the model or use of mathematical formulas are not intended.]

d. Construct an argument that explains the effect of adding or removing thermal energy to a pure substance in different phases and during a phase change in terms of atomic and molecular motion. [Assessment Boundary: The use of mathematical formulas is not intended.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a),(c)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables, and controls. (b)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (b)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- All substances are made from some 100 different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (a)
- Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (b)
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (d)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (c),(d)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (a)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (c),(d)

PS3.A: Definitions of Energy

- The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). (c),(d)
- Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (c),(d)

Crosscutting Concepts

Patterns

Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a)

Cause and Effect

Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (c),(d)

Structure and Function

Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (b)

Connections to other DCIs in this grade-level: **MS.ESS-ESP, MS.ESS-SS, MS.LS-MEOE**

Articulation of DCIs across grade-levels: **3.IF, 5.SPM, HS.PS.SPM, HS.PS-NP, HS.PS-E**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.5.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.5.4 Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

WHST.6-8.1 Write arguments focused on discipline-specific content.

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Mathematics –

MP.4 Model with mathematics.

MP.8 Look for and express regularity in repeated reasoning.

6.SP Develop understanding of statistical variability

Summarize and describe distributions

MS.PS-CR Chemical Reactions

MS.PS-CR Chemical Reactions

Students who demonstrate understanding can:

a. Develop representations showing how atoms regroup during chemical reactions to account for the conservation of mass. [Assessment Boundary: Representations should not involve bonding energy or valence electrons. Balancing equations are also not employed here.]

b. Generate and revise explanations from the comparison of the physical and chemical properties of reacting substances to the properties of new substances produced through chemical reactions to show that new properties have emerged. [Assessment Boundary: Comparison and analysis should not involve statistical techniques.]

c. Construct explanations of energy being released or absorbed when simpler molecules are combined into complex molecules or complex molecules are broken down to simpler molecules. [Clarification Statement: Simple molecules can include H_2O and CO_2, and complex molecules can include $C_6H_{12}O_6$ in photosynthesis.] [Assessment Boundary: Further details of the photosynthesis process are not addressed.]

d. Develop models to represent the movement of matter and energy in the cycling of carbon. [Clarification Statement: Examples of the movement of matter and energy could include the cycling from carbon in the atmosphere to carbon in living things.] [Assessment Boundary: Further details of the photosynthesis process are not addressed.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)
- Pose models to describe mechanisms at unobservable scales. (a)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct explanations for either qualitative or quantitative relationships between variables. (b)
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (c)

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (a),(b)
- The total number of each type of atom is conserved, and thus the mass does not change. (a),(c)
- Some chemical reactions release energy, others store energy. (c)

PS3.D: Energy in Chemical Processes and Everyday Life

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (c),(d)
- Both the burning of fuel and cellular digestion in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (d)

Crosscutting Concepts

Patterns

Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (b)

- [Clarification Statement for b: Comparing properties is a search for patterns; finding a change in pattern indicates a new substance.]

Energy and Matter

Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (a),(d)

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (c)

Connections to other DCIs in this grade-level: **MS.LS-SFIP, MS.LS-GDRO, MS.LS-MEOE, MS.ESS-WC, MS.ESS-ESP**

Articulation to DCIs across grade-levels: **5.SPM, HS.PS-CR, HS.PS-E, HS.LS-MEOE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.6.7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.

W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

W.6.8 Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.

W.7.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
MP.7 Look for and make use of structure.
MP.8 Look for and express regularity in repeated reasoning.
6.SP Develop understanding of statistical variability.
6.EE Represent and analyze quantitative relationships between dependent and independent variables.
7.SP.3 Draw informal comparative inferences about two populations.

MS.PS-E Energy

MS.PS-E Energy

Students who demonstrate understanding can:

- **a. Construct an explanation of the proportional relationship pattern between the kinetic energy of an object and its mass and speed.** [Assessment Boundary: Not intended to solely require use of $KE=1/2mv^2$—the explanation requires a qualitative description of the relationship and patterns.]
- **b. Use representations of potential energy to construct an explanation of how much energy an object has when it's in different positions in an electrical, gravitational, and magnetic field.** [Clarification Statement: Examples of objects in different field positions include a roller coaster cart at varying positions on a hill, objects at varying heights on shelves, an iron nail being moved closer to a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair.] [Assessment Boundary: Qualitative, not quantitative.]
- **c. Plan and carry out investigations to show that in some chemical reactions energy is released or absorbed.** [Clarification Statement: Examples of chemical reactions can include baking soda reacting with vinegar, and calcium chloride reacting with baking soda.] [Assessment Boundary: Qualitative, not quantitative.]
- **d. Use and/or construct models to communicate the means by which thermal energy is transferred during conduction, convection, and radiation.** [Clarification Statement: Examples of models can include a diagram depicting thermal energy transfer through a pan to its handle or warmer water in a pan rising as cooler water sinks; and a model using a heat lamp for the sun and a globe for the earth.]
- **e. Collect data and generate evidence to examine the relationship between the change in the temperature of a sample and the nature of the matter, the size of the sample, and the environment.** [Clarification Statement: Examples of data collection could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature.]
- **f. Compare, evaluate, and design a device that maximizes or minimizes thermal energy transfer, and defend the selection of materials chosen to construct the device.** [Assessment Boundary: Excludes semiconductors and heat sinks.]
- **g. Design and evaluate solutions that minimize and/or maximize friction and energy transfer in everyday machines.** [Clarification Statement: Solutions can include use of oil as a lubricant on a skateboard, bicycle, or in a lawnmower engine, and wax on skis. Energy transfer can include the transfer of energy from motion to thermal energy due to friction. Everyday machines can include skateboards, bicycles, lawnmowers, skis, and toy cars.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (c)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Use qualitative and quantitative relationships between variables to construct explanations for phenomena. (a)
- Construct explanations from models or representations. (b)
- Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (f),(g)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (f)

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (a)
- A system of objects may also contain stored (potential) energy, depending on their relative positions. For example, energy is stored—in gravitational interaction with Earth—when an object is raised, and energy is released when the object falls or is lowered. Energy is also stored in the electric fields between charged particles and the magnetic fields between magnets, and it changes when these objects are moved relative to one another. (b)
- Stored energy is decreased in some chemical reactions and increased in others. (c)
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (d),(e)

PS3.B: Conservation of Energy and Energy Transfer

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. For example, the friction that causes a moving object to stop also results in an increase in the thermal energy in both surfaces; eventually heat energy is transferred to the surrounding environment as the surfaces cool. Similarly, to make an object start moving or to keep it moving when friction forces transfer energy away from it, energy must be provided from, say, chemical (e.g., burning fuel) or electrical (e.g., an electric motor and battery) processes. (f),(g)
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (e)
- Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. (d)

PS3.D: Energy in Chemical Processes and Everyday Life

- Machines can be made more efficient, that is, require less fuel input to perform a given task, by reducing friction between their moving parts and through aerodynamic design. Friction increases energy transfer to the surrounding environment by heating the affected materials. (f),(g)

Crosscutting Concepts

Scale, Proportion, and Quantity

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (a),(b)

Energy and Matter

Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (c)

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (d),(e)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (f),(g)

MS.PS-E Energy *(continued)*
Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.LS-MEOE, MS.ETS-ED**
Articulation to DCIs across grade-levels: **4.E, HS.PS-E, HS.PS-FE**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **W.6.1** Write arguments to support claims with clear reasons and relevant evidence **W.7.1** Write arguments to support claims with clear reasons and relevant evidence **W.8.1** Write arguments to support claims with clear reasons and relevant evidence **WHST.7** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.4** Model with mathematics. **5.MD** Represent and interpret data. **6.RP** Understand ratio concepts and use ratio reasoning to solve problems. **6.EE** Apply and extend previous understandings of arithmetic to algebraic expressions Represent and analyze quantitative relationships between dependent and independent variables. **7.RP** Analyze proportional relationship and use them to solve real-world and mathematical problems. **7.EE** Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-FM Forces and Motion

MS.PS-FM Forces and Motion

Students who demonstrate understanding can:

a. Formulate questions arising from investigating how an observer's frame of reference and the choice of units influence how the motion and position of an object can be described and communicated to others. [Clarification Statement: Examples of different reference frames or choices of units are: A moving observer versus a stationary observer; observers facing different directions; and cm for short distances but km for long distances.] [Assessment Boundary: Observations are made at the macroscopic scale only.]

b. Communicate observations and information graphically and mathematically to represent how an object's relative position, velocity, and direction of motion are affected by forces acting on the object. [Assessment Boundary: Restricted to motion in one dimension. The use of vectors is not an expectation.]

c. Collect data to generate evidence supporting Newton's Third Law, which states that when two objects interact they exert equal and opposite forces on each other. [Clarification Statement: Examples of interacting objects can include a book resting on a table; and skaters facing one another with hands together, then pushing off of one another.] [Assessment Boundary: Restrict to vertical or horizontal interactions; interactions at angles requiring trigonometry is not an expectation.]

d. Use mathematical concepts and observations to describe the proportional relationship between the acceleration of an object and the force applied upon the object, and the inversely proportional relationship of acceleration to its mass. [Clarification Statement: Examples of these proportional and inversely proportional relationships can include a large truck requiring more force to slow down from a given speed to a stop than does a small truck and a ball pushed with a given force having a greater change in motion if the force is greater.] [Assessment Boundary: Simple formulas such as F=ma and w=mg could be used quantitatively; the use of trigonometry is not an expectation.]

e. Plan and carry out investigations to identify the effect forces have on an object's shape and orientation. [Clarification Statement: Effects of forces can include a small ball of mud or clay changing shape if force is added, such as pushing down on it or rolling it in your hands; and the orientation of a pencil on a desk changing if a force is applied to it.] [Assessment Boundary: When discussing an object's shape, description is purely qualitative. Simple formulas such as s=d/t and F=ma can be used quantitatively.]

f. Analyze and interpret data to determine the cause and effect relationship between the motion of an object and the sum of the forces acting upon it. [Clarification Statement: An example of the additive impact of forces on the motion of an object could include a situation in which one person may not be able to push a heavy object, but several people pushing and pulling in the same direction may move it.] [Assessment Boundary: Simple free-body diagrams are acceptable. The use of trigonometry is not an expectation. Assessments should include situations with both balanced and unbalanced forces.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.

- Ask questions that arise from phenomena, models, or unexpected results. (a)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (c),(e)

Analyzing and Interpreting Data

Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Distinguish between causal and correlational relationships. (f)

Mathematical and Computational Thinking

Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical concepts such as ratios, averages, basic probability, and simple functions, including linear relationships, to analyze data. (d)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluate the merit and accuracy of ideas and methods.

- Communicate understanding of scientific information that is presented in different formats (e.g., verbally, graphically, textually, mathematically). (b)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (c)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. (b),(f)
- The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (d)
- Forces on an object can also change its shape or orientation. (e)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (a)

Crosscutting Concepts

Scale, Proportion, and Quantity

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (a)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (b),(d)

Stability and Change

Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (c),(e),(f)

MS.PS-FM Forces and Motion
Connections to other DCIs in this grade-level: **MS.ESS-EIP, MS.ESS-SS**
Articulation to DCIs across grade-levels: **3.FI, HS.PS-FM, HS.PS-IF**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RST.3** Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks **WHST.9** Draw evidence from informational texts to support analysis reflection, and research. *Mathematics –* **MP 1** Make sense of problems and persevere in solving them **MP.2** Reason abstractly and quantitatively. **MP 4** Model with mathematics **MP.6** Attend to precision. **5.OA** Analyze patterns and relationships. **6.RP** Understand ratio concepts and use ratio reasoning to solve problems. **6.EE** Apply and extend previous understandings of arithmetic to algebraic expressions. Reason about and solve one-variable equations and inequalities. Represent and analyze quantitative relationships between dependent and independent variables. **7.RP** Analyze proportional relationships and use them to solve real-world and mathematical problems. **7.EE** Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-IF Interactions of Forces

MS.PS-IF Interactions of Forces

Students who demonstrate understanding can:

a. Plan and carry out investigations to illustrate the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Investigations can include observing the electric force produced between two charged objects at different distances; and measuring the magnetic force produced by an electromagnet with a varying number of wire turns, number or size of dry cells, or size of iron core.] [Assessment Boundary: Qualitative, not quantitative; no assessment of Coulomb's law.]

b. Use a model or various representations to describe the relationship among gravitational force, the mass of the interacting objects, and the distance between them. [Clarification Statement: Examples of models and representations can include labeled diagrams of the relationship between Earth and man-made satellites, the International Space Station, and an airplane taking off.] [Assessment Boundary: Qualitative, not quantitative.]

c. Plan and carry out investigations to demonstrate that some forces act at a distance through fields. [Assessment Boundary: Fields included are limited to gravitational, electric, and magnetic. Determination of fields are qualitative not quantitative (e.g., forces between two human–scale objects are too small to measure without sensitive instrumentation.)]

d. Develop a simple model using given data that represents the relationship of gravitational interactions and the motion of objects in space. [Clarification Statement: Examples of simple models can include charts displaying mass, distance from the sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Use models to determine a relationship conceptually. Qualitative, not quantitative.]

e. Develop or modify models to demonstrate that systems can withstand small changes, relying on feedback mechanisms to maintain stability. [Assessment Boundary: Use models to determine a relationship conceptually, not quantitatively.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (b),(d)
- Pose models to describe mechanisms at unobservable scales. (b),(d)
- Modify models – based on their limitations – to increase detail or clarity, or to explore what will happen if a component is changed. (e)
- Use and construct models of simple systems with uncertain and less predictable factors. (e)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (a),(c)

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (a)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (d)
- Long-range gravitational interactions govern the evolution and maintenance of large-scale systems in space, such as galaxies or the solar system, and determine the patterns of motion within those structures. (b),(d)
- Forces that act at a distance (gravitational, electric, and magnetic) can be explained by force fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). (c)

PS2.C: Stability and Instability in Physical Systems

- A stable system is one in which any small change results in forces that return the system to its prior state (e.g., a weight hanging from a string). (e)
- Many systems, both natural and engineered, rely on feedback mechanisms to maintain stability, but they can function only within a limited range of conditions. With no energy inputs, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., sand in an hourglass). (e)

Crosscutting Concepts

Cause and Effect

Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(b),(e)

Scale, Proportion, and Quantity

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (c),(d)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (d)

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.ESS-EIP, MS.ESS-ESP, MS.ESS-WC**

Articulation to DCIs across grade-levels: **3.FI, HS.PS-IF**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP 1 Make sense of problems and persevere in solving them.

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.6 Attend to precision.

5.OA Analyze patterns and relationships.

6.EE Represent and analyze quantitative relationships between dependent and independent variables.

7.RP Analyze proportional relationship and use them to solve real-world and mathematical problems.

7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-WER Waves and Electromagnetic Radiation

MS.PS-WER Waves and Electromagnetic Radiation

Students who demonstrate understanding can:

a. **Use a drawing or physical representation of simple wave properties to explain brightness and color.** [Assessment Boundary: Qualitative, not quantitative. Restricted to the following wave properties: frequency, wavelength, and amplitude.]

b. **Plan and carry out investigations of sound traveling through various types of mediums and lack of medium to determine whether a medium is necessary for the transfer of sound waves.** [Clarification Statement: Examples of investigations examining a lack of medium could include using a vacuum bell jar.]

c. **Construct explanations of how waves are reflected, absorbed, or transmitted through an object, considering the material the object is made from and the frequency of the wave.** [Assessment Boundary: Qualitative application to light, sound, and seismic waves only.]

d. **Use empirical evidence to support the claim that light travels in straight lines except at surfaces between different transparent materials.** [Clarification Statement: Examples of surfaces between transparent materials can include air and water, and air and glass.] [Assessment Boundary: Only non-computational observations; alterations of the speed of waves is not assessed until high school.]

e. **Ask questions about certain properties of light that can be explained by a wave model of light.** [Clarification Statement: Examples of properties of light can include brightness, color, and the refracting of light in a prism.]

f. **Apply scientific knowledge to explain the application of waves in common communication designs.** [Clarification Statement: Examples of common communication designs can include cell phones, radios, remote controls, and Bluetooth.] [Assessment Boundary: Applications limited to ability to transmit, receive, and encode.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.

- Ask questions that arise from phenomena, models, or unexpected results. (e)

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (b)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Use qualitative and quantitative relationships between variables to construct explanations for phenomena. (c)
- Apply scientific knowledge to explain real-world examples or events. (f)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (d)

Disciplinary Core Ideas

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (a)
- A sound wave needs a medium through which it is transmitted. (b)
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (c)

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (c)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. Lenses and prisms are applications of this effect. (d)
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (prisms). However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (a),(e)

PS4.C: Information Technologies and Instrumentation

- Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. Designers of such devices must understand both the signal and its interactions with matter. (f)
- Many modern communication devices use digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information. (f)

Crosscutting Concepts

Systems and System Models

Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (b),(e)

Structure and Function

Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (a),(c),(d),(f)

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.ESS-ESP, MS.ESS-EIP**

Articulation to DCIs across grade-levels: **3.SFS, 4.WAV, 5.SSS, HS.PS-W, HS.PS-ER, HS.PS-FM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

SL.6.3 Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.

SL.7.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.

SL.8.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

RST.6-8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.6 Attend to precision.

6.EE Represent and analyze quantitative relationships between dependent and independent variables.

HS.PS-SPM Structure and Properties of Matter

HS.PS-SPM Structure and Properties of Matter

Students who demonstrate understanding can:

a. Construct models showing that stable forms of matter are those with minimum magnetic and electrical field energy. [Clarification Statement: Examples of stable forms of matter can include noble gas atoms, simple molecules, and simple ionic substances.] [Assessment Boundary: Only for common substances- for example, water, carbon dioxide, common hydrocarbons, sodium chloride.]

b. Construct various types of models showing that energy is needed to take molecules apart and that energy is released when the atoms come together to form new molecules. [Assessment Boundary: Only for common substances (e.g., water, carbon dioxide, common hydrocarbons, sodium chloride]

c. Develop explanations about how the patterns of electrons in the outer level of atoms, as represented in the periodic table, reflect and can predict properties of elements. [Clarification Statement: An example of a pattern that predicts element properties is the first column of the periodic table: These elements all have one electron in the outer most energy level and as such are all highly reactive metals.] [Assessment Boundary: Only for main group elements (not transition metals or elements beyond the third row).]

d. Construct arguments for which type of atomic and molecular representation best explains a given property of matter. [Clarification Statement: Types of atomic and molecular representations can include computer-based, simulations, physical, ball and stick, and symbolic. Properties of matter can include reactivity, and polar vs. non-polar.] [Assessment Boundary: Not theoretical models]

e. Analyze and interpret data obtained from measuring the bulk properties of various substances to explain the relative strength of the interactions among particles in the substance. [Clarification Statement: Bulk properties of substances can include melting point and boiling point.] [Assessment Boundary: Comparisons between ionic and molecular species or network and molecular species are included, but those that require understanding of different intermolecular forces are not included. Only the following types of particles are included in data and explanations: atoms, ions, and molecules.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (b)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (c)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the merits of competing arguments, design solutions and/or models. (d)
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (c),(d)
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (c)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (e)
- Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (a),(b)

PS2.B: Types of Interactions

- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (d),(e)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b),(c),

- [Clarification Statement for a: Stability is caused by minimization of energy.]
- [Clarification Statement for c: The likelihood of interactions between elements is caused by the number of electrons in their valence shell, and thus the arrangement of the periodic table.]

Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (d)

Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (e)

- [Clarification Statement for e: The relative strength of interactions among particles causes different bulk properties.]

Connections to other DCIs in this grade-level: **HS.LS-MEOE, HS.ESS-SS, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-SPM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

SL.9-10.2 Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.

RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), nothing when the findings support or contradict previous explanations or accounts.

SL.11-12.2 Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics –

MP.4 Model with mathematics.

8.F Use functions to model relationships between quantities

S.ID Summarize, represent, and interpret data on two categorical and quantitative variables

S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.PS-CR Chemical Reactions

HS.PS-CR Chemical Reactions

Students who demonstrate understanding can:

a. **Analyze and interpret data to support claims that energy of molecular collisions and the concentration of the reacting particles affect the rate at which a reaction occurs.** [Assessment Boundary: Limited to simple (zero or first order in each reactant) reactions. The exact relationship between rate and temperature is not required.]

b. **Develop and use models to explain that atoms (and therefore mass) are conserved during a chemical reaction.** [Clarification Statement: Models can include computer models, ball and stick models, and drawings.] [Assessment Boundary: Stoichiometric calculations are not required.]

c. **Analyze and interpret data to make claims that reaction conditions can be used to optimize the output of a chemical process.** [Assessment Boundary: Limited to simple reactions. Reaction conditions are limited to temperature, pressure, and concentrations of all substances in the system.]

d. **Construct mathematical models to explain how energy changes in chemical reactions are caused by changes in binding energy as the reactants form products and in which changes in the kinetic energy of the system can be detected as change in temperature.** [Assessment Boundary: Limited to calculating the change in binding energy and resulting change in thermal energy for simple chemical reactions, (i.e., reactions of simple hydrocarbons with oxygen).]

e. **Construct and communicate explanations using the structure of atoms, trends in the periodic table and knowledge of the patterns of chemical properties to predict the outcome of simple chemical reactions.** [Assessment Boundary: Only those chemical reactions readily predictable from the element's position on the periodic table and combustion reactions are intended.]

f. **Construct and communicate explanations that show how chemical processes and/or properties of materials are central to biological and geophysical systems.** [Clarification Statement: Chemical processes can include oxidation of hydrocarbons, and the reaction of CO_2 and H_20 to give hydrocarbons. Properties of materials can include water expanding when freezing.] [Assessment Boundary: Restricted to overall chemical processes (for example, oxidation of carbon compounds), or construction of carbon compounds (photosynthesis); details of biochemical pathways are not required (for example, Krebs Cycle).]

g. **Use system models (computer or drawings) to construct molecular-level explanations to predict the behavior of systems where a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.** [Assessment Boundary: Limited to simple reactions, adding or removing one reactant or product at a time.]

h. **Construct explanations using data from system models or simulations to support the claim that systems with many molecules have predictable behavior, but that the behavior of individual molecules is unpredictable.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (b)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (b),(g)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (d)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (a),(c)
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. (a),(c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative claims regarding the relationship between dependent and independent variables. (h)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (h)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e),(f)

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. (a),(d)
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (c),(g)
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (b),(e)
- Chemical processes and properties of materials underlie many important biological and geophysical phenomena. (f)

PS2.C: Stability and Instability in Physical Systems

- When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). (h)

PS3.A: Definitions of Energy

- "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized. (d)

Crosscutting Concepts

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identify some patterns. (e),(f)

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b),(c),(d),(h)

Energy and Matter

The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (g)

- [Clarification Statement for g: Dynamic and condition-dependent balances are dependent on matter and energy flows.]

HS.PS-CR Chemical Reactions *(continued)*
Connections to other DCIs in this grade-level: **HS.ETS-ED, HS.LS-SFIP, HS.LS-MEOE, HS.ESS-ES**
Articulation to DCIs across grade-levels: **MS.PS-CR**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **W.8.8** Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. **RST.9-10.9** Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. **RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.4** Model with Mathematics **8.SP** Investigate patterns of association in biivariate data. **S.ID** Summarize, represent, and interpret data on a single count or measurement variable **A-CED.1** Create equations that describe numbers or relationships

HS.PS-E Energy

HS.PS-E Energy

Students who demonstrate understanding can:

a. Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system. [Assessment Boundary: Computational accounting for energy in a system limited to systems of two or three components.]

b. Identify problems and suggest design solutions to optimize the energy transfer into and out of a system. [Clarification Statement: Design solution examples can include insulation, microchip temperature control, cooking electronics, and roller coaster design.] [Assessment Boundary: Limited to mechanical and thermal systems.]

c. Analyze data to support claims that closed systems move toward more uniform energy distribution.

d. Design a solution to minimize or slow a system's inclination to degrade to identify the effects on the flow of the energy in the system. [Clarification Statement: Examples of system degradation can include wearing down due to friction, increase in disorder, and radioactive decay.]

e. Construct models to show that energy is transformed and transferred within and between living organisms. [Assessment Boundary: Does not mean particular biological processes such as Krebs cycle.]

f. Construct models to represent and explain that all forms of energy can be viewed as either the movement of particles or energy stored in fields. [Assessment Boundary: Models representing field energies need not be mathematical.]

g. Construct representations that show that some forms of energy may be best understood at the molecular or atomic scale. [Clarification Statement: Forms of energy represented can include thermal, electromagnetic, and sound.] Assessment Boundary: Limited to conceptual understanding; quantitative representations are not required.]

h. Design, build, and evaluate devices that convert one form of energy into another form of energy. [Clarification Statement: Examples of devices can include roller coasters, Rube Goldberg devices, wind turbines, and generators.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (b)

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a),(f)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (e),(g)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to create explanation, computational models, or simulations. (a)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (b),(d),(h)

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. (a)
- That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (a),(e),(h)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. (h)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (f),(g)

PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (a),(h)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (b),(c),(e),(h)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (a),(c)
- The availability of energy limits what can occur in any system. (d)
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (c),(d),(e)
- Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). (d)

PS3.D: Energy in Chemical Processes

- The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (e)
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (h)
- A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions. (e)
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (b),(h)

Crosscutting Concepts

Systems and System Models

Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (a),(c),(d),(e),(f),(g),(h)

- [Clarification Statement for all PEs: Energy transfer cannot be directly studied- a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined]

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (b)

HS.PS-ECT Energy *(continued)*
Connections to other DCIs in this grade-level: **HS.LS-SFIP, HS.LS-MEOE, HS.ESS-CC, HS.ESS-HS, HS.ESS-ES, HS.ESS-SS, HS.ETS-ED, HS.ETS-ETSS**
Articulation to DCIs across grade-levels: **MS.PS-E, MS.PS-CR**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **SL.1.c** Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives. **SL.9-10.2** Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. **RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. **RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.3** Construct viable arguments and critique the reasoning of others **MP.4** Model with Mathematics **MP.6** Attend to precision **A-REI.10** Represent and solve equations and inequalities graphically. **A.SSE** Interpret the structure of expressions. **A.CED** Create equations that describe numbers or relationships.

HS.PS-FM Forces and Motion

HS.PS-FM Forces and Motion

Students who demonstrate understanding can:

- **a. Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion.** [Assessment Boundary: Restricted to one- and two-dimensional motion and does not include rotational motion. Does not apply in the case of subatomic scales or for speeds close to the speed of light. Calculations restricted to macroscopic objects moving at non-relativistic speeds.]
- **b. Generate and analyze data to support the claim that the total momentum of a closed system of objects before an interaction is the same as the total momentum of the system of objects after an interaction.** [Clarification Statement: Conservation of momentum is the focus.]
- **c. Use algebraic equations to predict the velocities of objects after an interaction when the masses and velocities of objects before the interaction are known.** [Assessment Boundary: Restricted to macroscopic interactions and only two objects moving in one or two dimensions.]
- **d. Design and evaluate devices that minimize the force on a macroscopic object during a collision.**
- **e. Construct a scientific argument supporting the claim that the predictability of changes within systems can be understood by defining the forces and changes in momentum both inside and outside the system.** [Assessment Boundary: Restricted to macroscopic interactions.]
- **f. Communicate arguments to support claims that Newton's laws of motion apply to macroscopic objects but not to objects at the subatomic scales or speeds close to the speed of light.** [Assessment Boundary: No details of quantum physics or relativity are included.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims. (b)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (d)
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (e),(f)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. (a),(e),(f)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (b)
- In any system, total momentum is always conserved. (b),(c)
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (c),(d),(e)

PS2.C: Stability and Instability in Physical Systems

- Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from outside, helps predict its behavior under a variety of conditions. (d),(e)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(c),(d)

Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (b),(e)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (d)

HS.PS-FM Forces and Motion *(continued)*	
Connections to other DCIs in this grade-level: **HS.ETS-ED, HS.ESS-SS, HS.ESS-ES**	
Articulation to DCIs across grade-levels: **MS.PS-FM, MS.PS-WER**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
WHST.9	Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with Mathematics
MP.5	Use appropriate tools strategically
8.F	Define, evaluate, and compare functions.
S.ID	Summarize, represent, and interpret data on a single count or measurement variable
F.BF	Build a function that models a relationship between two quantities
N-Q	Reason quantitatively and use units to solve problems

HS.PS-FE Forces and Energy

HS.PS-FE Forces and Energy

Students who demonstrate understanding can:

a. Plan and carry out investigations in which a force field is mapped to provide evidence that forces can transmit energy across a distance. [Assessment Boundary: Mapping limited to the direction of the force field.]

b. Develop arguments to support the claim that when objects interact at a distance, the energy stored in the field changes as the objects change relative position. [Clarification Statement: An example of this phenomenon could include repelling magnets moving apart, reducing the repelling force and the strength of the field between them.] [Assessment Boundary: Qualitative comparisons only.]

c. Evaluate natural and designed systems where there is an exchange of energy between objects and fields and characterize how the energy is exchanged. [Clarification Statement: Examples of these systems could include motors, generators, speakers, microphones, planets orbiting a start.] [Assessment Boundary: Characterizations limited to qualitative descriptors.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (c)

Disciplinary Core Ideas

PS3.C: Relationship Between Energy and Forces

- Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another. (a)
- When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (b),(c)
- Each force between the two interacting objects acts in the direction such that motion in that direction would reduce the energy in the force field between the objects. However, prior motion and other forces also affect the actual direction of motion. (c)

Crosscutting Concepts

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. (a),(b)

- [Clarification Statement for a: Mapping force fields requires evidence of the pattern of the field lines]
- [Clarification Statement for b: Coulomb's law: Proportion is a pattern.]
- [Clarification Statement for c: A pattern of energy transfer will be apparent.]

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (c)

Connections to other DCIs in this grade-level: **HS.ESS-SS, HS.ESS-ES, HS.ESS-CC, HS.ETS-ETSS**

Articulation to DCIs across grade-levels: **MS.PS-E**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with Mathematics.

F.BF Build a function that models a relationship between two quantities.

A.CED Create equations that describe numbers or relationships.

HS.PS-IF Interactions of Forces

HS.PS-IF Interactions of Forces

Students who demonstrate understanding can:

a. Use mathematical expressions to determine the relationship between the variables in Newton's Law of Gravitation and Coulomb's Law, and use these to predict the electrostatic and gravitational forces between objects. [Assessment Boundary: Only situations with two objects are predicted.]

b. Use models to demonstrate that electric forces at the atomic scale affect and determine the structure, properties (including contact forces), and transformations of matter. [Clarification statement: Models can include graphical and computer models. Examples of properties and transformations of matter can include intermolecular forces, chemical bonding, and enzyme substrate interaction.] [Assessment Boundary: Only a qualitative understanding is expected.]

c. Plan and carry out investigations to demonstrate the claim that magnets, electric currents, or changing electric fields cause magnetic fields and electric charges or changing magnetic fields cause electric fields. [Assessment Boundary: Qualitative observations only.]

d. Obtain, evaluate, and communicate information to show that strong and weak nuclear interactions inside atomic nuclei determine which nuclear isotopes are stable, and that the pattern of decay of an unstable nucleus can often be predicted. [Clarification Statement: Types of decay in unstable nuclei can include alpha or beta radiation.] [Assessment Boundary: Only a qualitative understanding of nuclear interactions is expected.]

e. Obtain, evaluate, and communicate information to show how scientists and engineers take advantage of the effects of electrical and magnetic forces in materials to design new devices and materials through a process of research and development. [Clarification Statement: Designed devices can include magnetic strips on credit cards, laser printers, and photo copiers.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Construct, revise, and use models to predict and explain relationships between systems and their components. (b)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects and ensure the investigation's design has controlled for them. (c)

Using Mathematical and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Generate, synthesize, communicate, and critique claims, methods and designs that appear in scientific and technical texts or media reports. (d),(e)

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (a)
- Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (c)
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (b),(e)
- The strong and weak nuclear interactions are important inside atomic nuclei—for example, they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones. (d)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b),(c),(d)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (e)

Connections to other DCIs in this grade-level: **HS.ETS-ETSS, HS.ESS-SS, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-IF, MS.PS-FM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively

MP.4 Model with Mathematics

8.F Define, evaluate, and compare functions.

S.ID Summarize, represent, and interpret data on a single count or measurement variable

F.BF Build a function that models a relationship between two quantities

HS.PS-W Waves

HS.PS-W Waves

Students who demonstrate understanding can:

a. Plan and carry out investigations to determine the mathematical relationships among wave speed, frequency, and wavelength and how they are affected by the medium through which the wave travels. [Assessment Boundary: Algebraic calculations only.]

b. Carry out an investigation to describe a boundary between two media that affects the reflection, refraction, and transmission of waves crossing the boundary. [Clarification Statement: Descriptions should include mathematical relationships.] [Assessment Boundary: Descriptions requiring trigonometric functions are excluded.]

c. Investigate the patterns created when waves of different frequencies combine and explain how these patterns are used to encode and transmit information. [Assessment Boundary: Qualitative only.]

d. Use drawings, physical replicas, or computer simulation models to explain that resonance occurs when waves add up in phase in a structure, and that structures have a unique frequency at which resonance occurs. [Clarification Statement: Constructive and destructive interference of waves results in a standing wave pattern (resonance).] [Assessment Boundary: Qualitative explanations only.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (d)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a),(b),(c)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (b)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (c)

Disciplinary Core Ideas

PS4.A: Wave Properties

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties. (a),(b)
- Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. (c)
- Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments. (d)

Crosscutting Concepts

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. (a),(c),(d)

- [Clarification Statement for d: Constructive and destructive interference of waves results in a standing wave pattern, i.e. resonance.]

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (b)

Connections to other DCIs in this grade-level: **HS-ETS-ETSS, HS-ETS-ED, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-WER**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with Mathematics.

F.LE Construct and compare linear, quadratic, and exponential models and solve problems.

A-REI.10 Represent and solve equations and inequalities graphically.

A.CED Create equations that describe numbers or relationships.

HS.PS-ER Electromagnetic Radiation

Students who demonstrate understanding can:

a. Use arguments to support the claim that electromagnetic radiation can be described using both a wave model and a particle model, and determine which model provides a better explanation of phenomena. [Assessment Boundary: Limited to understanding that the quantum theory relates the two models, but students do not need to know the specifics of the quantum theory.]

b. Obtain, evaluate, and communicate scientific literature to show that all electromagnetic radiation travels through a vacuum at the same speed (called the speed of light).

c. Obtain, evaluate, and communicate scientific literature about the effects different wavelengths of electromagnetic radiation have on matter when the matter absorbs it. [Assessment Boundary: Only IR, UV, and gamma radiation are intended; qualitative descriptions only.]

d. Analyze and interpret data of both atomic emission and absorption spectra of different samples to make claims about the presence of certain elements in the sample. [Assessment Boundary: Identification of elements to be based on comparison of spectral lines.]

e. Construct an explanation of how photovoltaic materials work using the particle model of light, and describe their application in everyday devices. [Clarification Statement: Everyday devices can include solar cells and barcodes.] [Assessment Boundary: Qualitative descriptors only]

f. Obtain, evaluate, and communicate scientific literature about the differences and similarities between analog and digital representations of information to describe the relative advantages and disadvantages. [Assessment Boundary: Qualitative explanations only.]

g. Construct explanations for why the wavelength of an electromagnetic wave determines its use for certain applications. [Clarification Statement: Examples of wavelength determining applications can include visible light not being used to observe atoms, and x-rays being used for bone imaging.] [Assessment Boundary: Only qualitative descriptors in the explanation are intended.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and models (e.g. computational and mathematical) to plan, gather, and analyze data to make valid and reliable scientific claims or justify an optimal solution. (d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e),(g)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Construct a counter-argument that is based in data and evidence that challenges another proposed argument. (a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (b),(c),(f)

Disciplinary Core Ideas

PS4.A: Wave Properties

- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (f)

PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.) (a)
- Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. (g)
- All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium. (b),(g)
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (c),(g)
- Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (c),(g)
- Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. (e)
- Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities. (d)

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (e),(f),(g)
- Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communication, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.) (g)

Crosscutting Concepts

Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (a),(b),(d),(e)

- [Clarification Statement for a: The way something functions, e.g. visible light, can be best understood through a particular representation of its structure.]
- [Clarification Statement for d: Rationale is that from the spectra (the way they function) the structure can be inferred.]

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c),(f),(g)

HS.PS-ER Electromagnetic Radiation *(continued)*
Connections to other DCIs in this grade-level: **HS.ETS-ETSS, HS.ESS-SS**
Articulation to DCIs across grade-levels: **MS.PS-WER**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.9-10.8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning. **SL.9-10.4** Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task. **SL.11-12.4** Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. *Mathematics –* **N-Q** Reason quantitatively and use units to solve problems **S.ID** Summarize, represent, and interpret data on a single count or measurement variable **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.PS-NP Nuclear Processes

HS.PS-NP Nuclear Processes

Students who demonstrate understanding can:

a. Construct models to explain changes in nuclear energies during the processes of fission, fusion, and radioactive decay and the nuclear interactions that determine nuclear stability. [Assessment Boundary: Models to exclude mathematical representations. Radioactive decays limited to alpha, beta, and gamma.]

b. Analyze and interpret data sets to determine the age of samples (rocks, organic material) using the mathematical model of radioactive decay. [Assessment Boundary: Mathematical model limited to graphical representations.]

c. Ask questions and make claims about the relative merits of nuclear processes compared to other types of energy production. [Clarification Statement: Students are given data about energy production methods, such as burning coal versus using nuclear reactors.] [Assessment Boundary: Students only analyze data provided. Merits only include economic, safety, and environmental]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.
- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (c)

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.
- Construct, revise, and use models to predict and explain relationships between systems and their components. (a)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Use tools, technologies, and models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (b),(c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Students also use and create simple computational simulations based on mathematical models of basic assumptions.
- Use statistical and mathematical techniques and structure data (e.g., displays, tables, and graphs) to find regularities, patterns (e.g., fitting mathematical curves to data), and relationships in data. (b)

Disciplinary Core Ideas

PS1.C: Nuclear Processes
- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. (a) The total number of neutrons plus protons does not change in any nuclear process. (a)
- Strong and weak nuclear interactions determine nuclear stability and processes. (a)
- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. (b)

PS3.D: Energy in Chemical Processes and Everyday Life
- All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. (c)

Crosscutting Concepts

Energy and Matter
The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (a)

Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (b)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c)

Connections to other topics in this grade-level: **HS.ESS-SS, HS.ESS-HE, HS.ETS-ETSS**

Articulation across grade-levels: **MS.PS-SPM, MS.LS-NSA**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.1.c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

W.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

W.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

Mathematics –

MP.4 Model with Mathematics

F.LE Construct and compare linear, quadratic, and exponential models and solve problems

A-CED.1 Create equations that describe numbers or relationships

N-Q Reason quantitatively and use units to solve problems

MS-ETS-ED Engineering Design

Students who demonstrate understanding can:

- **a. Evaluate ideas for solving an environmental problem to determine which designs best meet the criteria and constraints of the problem and take into account scientific principles and short and long-term consequences.** [Clarification Statement: Students compare sand blasting, chemical solvent, and high heat for removing graffiti; evaluate different plans for solving problems due to invasive species.] [Assessment Boundary: A numerical weighting system may be used to evaluate designs, but not an advanced mathematical model.]
- **b. Develop a better design by combining characteristics of different solutions to arrive at a design that takes into account relevant scientific principles and better meets the needs of society.** [Clarification Statement: For example, students develop a design for a highly energy efficient automobile by combining ideas from different car ads.] [Assessment Boundary: Limit arguments to qualitative characteristics.]
- **c. Compare different designs by building physical models and running them through the same kinds of tests, while systematically controlling variables and recording the results to determine which design performs best.** [Clarification Statement: For example, students test different designs for a bridge by building and testing a model or compare different designs for a hydroponic farm by building and testing small scale models in the classroom.]
- **d. Use a computer simulation to test the effectiveness of a design under different operating conditions, or test what would happen if perameters of the model were changed, noting how the simulation may be limited in accurately modeling the real world.** [Clarification Statement: Examples include simulating how a solar hot water system would function in different seasons or parts of the world and simulating the effects of different preventive actions in slowing the spread of disease during an epidemic.] [Assessment Boundary: Students should be given simulation software to use and not expected to create their own.]
- **e. Refine a design by conducting several rounds of tests, modifying the model after each test, to create the best possible design that meets the most important criteria.** [Clarification Statement: For example, students refine the design of a model building to withstand an earthquake, strengthening failure points after each test, or refine the design of a water filtration system by adding physical and chemical components and retesting after each change.]
- **f. Communicate information about a proposed solution to a problem, including relevant scientific principles, how the design was developed, how it meets the criteria and constraints of the problem, and how it reduces the potential for negative consequences for society and the natural environment.** [Clarification Statement: Students develop a poster, slide presentation, or oral design concept presentation.] [Assessment Boundary: Arguments should be limited to qualitative characteristics.]

The performance expectations above were developed using the following elements from the NRC *A Framework for K – 12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on 3-5 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (c)
- Collect data and generate evidence to answer scientific questions or test design solutions. (c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. (d)
- Use mathematical arguments to justify scientific conclusions and design solutions. (d)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (b),(e)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluate the merit and validity of ideas and methods.
- Generate and communicate ideas and methods using scientific language and reasoning. (a),(f)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting an Engineering Problem
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. (a)
- Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (a)

ETS1.B: Developing Possible Solutions
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (e)
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (a)
- It is important to be able to communicate and explain solutions to others. (f)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (b)
- Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. (d)
- Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback. (d)

ETS1.C: Optimizing the Design Solution
- Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. (c)
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process-that is, some of those characteristics may be incorporated into the new design. (c)
- This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (e)
- Once a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (f)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(e)

Systems and System Models
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (c),(d)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies from region to region and over time. (a),(b),(f)

MS-ETS-ED Engineering Design *(continued)*

Connections to other DCIs in this grade-level: **MS.ES-HI; MS.LS-GDRO; MS.PS-IF, MS.PS-E, MS.ETS-ETSS**

Articulation to DCIs across grade-levels: **1.SF, 2.ECS, 2.PP, 4.E, 4.PSE, 4.WAV, HS.ETS-ED**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
W.6.1 Write arguments to support claims with clear reasons and relevant evidence.
W.7.1 Write arguments to support claims with clear reasons and relevant evidence.
W.8.1 Write arguments to support claims with clear reasons and relevant evidence.
WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP 1 Make sense of problems and persevere in solving them.
MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
MP.6 Attend to precision.
6.EE Apply and extend previous understandings of arithmetic to algebraic expressions.
Represent and analyze quantitative relationships between dependent and independent variables.
7.RP Analyze proportional relationship and use them to solve real-world and mathematical problems.
7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
8.F Use functions to model relationships between quantities.

MS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

MS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

Students who demonstrate understanding can:

a. Provide examples to explain how advances in engineering have resulted in new tools and instruments for measurement, exploration, modeling, and computation that enable new scientific discoveries, which in turn lead to the development of entire industries and engineered systems. [Clarification Statement: Examples include: microscopes enabled the germ theory of disease, which led to the development of antibiotics, stimulating growth of the pharmaceutical industry; discoveries in physics led to development of the integrated circuit, and computers, leading to many scientific breakthroughs, and spawning new industries.]

b. Obtain, evaluate, and communicate information about a technology that draws on natural resources to improve health of people and the natural environment, and was eventually found to have negative impacts, requiring regulations on its use or new technologies to reduce its negative impacts. [Clarification Statement: Examples include the introduction of new chemicals for refrigeration that were less toxic, but were later found to reduce the ozone layer; the adoption of fossil fuels for energy that eliminated the need to decimate forests for heating and cooking, but were later found to change the atmosphere and climate.]

c. Construct an explanation for how a technological system has changed over time, based on evidence about how these changes were driven by: (1) people's changing needs, desires, and values, (2) the findings of scientific research, and (3) factors such as climate, natural resources, and economic conditions. [Clarification Statement: Use diagrams, timelines, or other representations to show factors that have shaped a major technological system over time (e.g., energy, transportation, manufacturing, food production and distribution).] [Assessment Boundary: Explanations do not need to include all possible factors or be quantitative.]

d. Construct arguments for and against the development of a new technology based on potential short and long term impacts (positive and negative) on the health of people, and the natural environment. [Clarification Statement: Students should consider the pros and cons of different new technologies such as maglev rail, genetically engineered crops, wearable computers, human space travel, and new energy systems that exploit renewable resources.]

The performance expectations above were developed using the following elements from the NRC A Framework for *K – 12 Science Education*:

Science and Engineering Practices

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a),(c)
- Apply scientific knowledge to explain real-world examples or events and solve design problems. (a),(c)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.
- Generate and communicate ideas using scientific language and reasoning. (b)
- Gather, read, and explain information from appropriate sources and evaluate the credibility of the publication, authors, possible bias of the source, and methods used. (b)

Disciplinary Core Ideas

ETS2.A: Interdependence of Science, Engineering, and Technology
- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (a)
- In order to design better technologies, new science may need to be explored. (a)
- Technologies in turn extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (a)

ETS2.B: Influence of Engineering, Technology, and science on society and the natural world
- All human activity draws on natural resources and has both short-term and long-term consequences, positive as well as negative for the health of both people and the natural environment. (b),(d)
- The uses of technology and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (c),(d)
- Thus technology use varies from region to region and over time. (c)
- Technologies that are beneficial for a certain purpose may later be seen to have impacts that were not foreseen. In such cases, new regulations on use or new technologies may be required. (b),(d)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomenon may have more than one cause, and some cause, and effect relationships in systems can only be described using probability. (a),(c),(d)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (b),(c),(d)

Connections to other DCIs in this grade-level: **MS.ESS-ESP, MS.ESS-WC, MS.ESS-HI, MS.LS-GDRO, MS.PS-WER, MS.ETS-ED**

Articulation to DCIs across grade-levels: **3.IF, 3.WCI, 4.LCT, 4.WAV, 5.ESI, 5.SSS, HS.ETS-ETSS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
W.6.1 Write arguments to support claims with clear reasons and relevant evidence
W.7.1 Write arguments to support claims with clear reasons and relevant evidence
W.8.1 Write arguments to support claims with clear reasons and relevant evidence
WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP 1 Make sense of problems and persevere in solving them.
MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
MP.6 Attend to precision.
6.EE Apply and extend previous understandings of arithmetic to algebraic expressions
Represent and analyze quantitative relationships between dependent and independent variables.
7.RP Analyze proportional relationship and use them to solve real-world and mathematical problems.
7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
8.F Use functions to model relationships between quantities.

HS-ETS-ED Engineering Design

HS-ETS-ED Engineering Design

Students who demonstrate understanding can:

a. Ask questions and collect information to quantify the scope and impacts of a major global problem on local communities and find evidence of possible causes by breaking the problem down into parts and investigating the mechanisms that may contribute to each part. [Clarification Statement: For example, students ask questions to quantify the scope and impacts of acid rain in a local community by investigating the mechanisms involved in stone monument erosion.] [Assessment Boundary: Limit to asking questions and gathering information to better understand the problem and possible causes; not finding solutions.]

b. Analyze input and output data and functioning of a human-built system to define opportunities to improve the system's performance so it better meets the needs of end users while taking into account constraints (e.g., materials, costs, scientific principles). [Clarification Statement: Analyze data and functioning of a human-built system such as a school's heating and cooling system; or throughput and functioning of a city's wastewater system.]

c. Evaluate different solutions to a problem by identifying criteria (e.g., cost, safety, reliability, aesthetics) and possible impacts on society and the natural environment, and using a trade-off matrix or numerical weighting system to choose the best solution. [Clarification Statement: Example problems for which multiple solutions can be proposed and evaluated include deicing a parking lot, increasing yield of a garden or farm, or mining a natural resource with minimal environmental damage.]

d. Plan and carry out a quantitative investigation with physical models or prototypes to develop evidence on the effectiveness of design solutions, leading to at least two rounds of testing and improvement. [Clarification Statement: For example, physical models or prototypes to conduct a quantitative investigation to determine if an ultraviolet light can purify water equally well as a chlorine-based system.]

e. Use computational thinking to create, simulate, and compare different design solutions, checking to be certain that the simulation makes sense when compared with the real world. [Clarification Statement: For example, students create a computer simulation of a model building to see how different modifications could save energy and reduce CO_2 emissions.] [Assessment Boundary: Students use existing modeling software.]

f. Refine a solution by prioritizing criteria and taking into account the life cycle of a given product or technological system and factors such as safety, reliability, and aesthetics to achieve an optimal solution. [Clarification Statement: For example, choose the best possible heat pump technology for a campus building; determine the optimum method for extracting oil and natural gas; or best method for treating soil prior to planting crops.]

The performance expectations above were developed using the following elements from the NRC *A Framework for K – 12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.
- Ask questions that arise from phenomena, models, theory, or unexpected results. (a)
- Ask questions to determine quantitative relationships between independent and dependent variables. (a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9 – 12 builds on k – 8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.
- Plan and carry out investigations collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (d)
- Select appropriate tools to collect, record, analyze, and evaluate data. (d)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Use tools, technologies, and models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (b)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use simple limit cases to test mathematical expressions, computer programs or algorithms, or simulations to see if a model makes sense by comparing the outcomes with what is known about the real world. (e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting an Engineering Problem
- Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. (b)
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (b)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. But, whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions. (a)

ETS1.B: Developing Possible Solutions
- To design something complicated one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan. (a)
- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (c)
- Testing should lead to improvements in the design through an iterative procedure. Both physical models and computer models can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. (d)
- Computer models are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; in running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (e)

ETS1.C: Optimizing the Design Solution
- The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. Optimization can be complex for a design problem with numerous desired qualities or outcomes. Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (f)
- The comparison of multiple designs can be aided by a trade-off matrix. Sometimes a numerical weighting system can help evaluate a design against multiple criteria. When evaluating solutions, all relevant considerations, including cost, safety, reliability, and aesthetic, social, cultural, and environmental impacts, should be

Crosscutting Concepts

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(e)

Systems and System Models
Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions within and between systems at different scales. Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (b),(c),(d)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment,

HS-ETS-ED Engineering Design

HS-ETS-ED Engineering Design *(continued)*		
student-generated sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Apply scientific knowledge to solve design problems by engaging in all steps of the design cycle, taking into account possible unanticipated effects. (f) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science. ▪ Evaluate the merits of competing arguments, design solutions and/or models. (c)	included. (c) ▪ Testing should lead to design improvements through an iterative process, and computer simulations are one useful way of running such tests. (d)	some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c),(f)
Connections to other DCIs in this grade-level: **HS.ESS-CC, HS.ESS-HS, HS.PS-E, HS.ETS-ETSS**		
Articulation to DCIs across grade-levels: **MS.ETS-ED**		

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]
ELA –
RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –
MP.2 Reason abstractly and quantitatively
MP.4 Model with Mathematics
MP.5 Use appropriate tools strategically
8.F Define, evaluate, and compare functions.
S.ID Summarize, represent, and interpret data on a single count or measurement variable
S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies
F.BF Build a function that models a relationship between two quantities
F.LE Construct and compare linear, quadratic, and exponential models and solve problems
N-Q Reason quantitatively and use units to solve problems
A.CED Create equations that describe numbers or relationships.

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

Students who demonstrate understanding can:

a. Plan and carry out an investigation to improve a technology and suggest ideas for further related scientific study. [Clarification Statement: For example, a group of students investigate the environmental conditions needed to maintain a healthy aquatic population, apply findings to improving an aquarium, and recommend research that can be done with the improved technology to study aquatic ecosystems.]

b. Gather evidence to evaluate different explanations for the widespread adoption of a modern technology, including the role of societal demands, market forces, evaluations by scientists and engineers, and possible government regulation. [Clarification Statement: For example, students evaluate explanations for the rapid spread of cell phones, LED lighting, or genetically engineered crops for farming.)

c. Analyze data to compare different technologies designed to accomplish the same function regarding their relative environmental impacts, costs, risks, and benefits, and what may need to be done to reduce unanticipated negative effects. [Clarification Statement: Comparisons include paper vs. electronic books, nuclear vs. coal-fired power plants.] [Assessment Boundary: Analysis limited to data available online or provided to students.]

d. Construct or critique arguments based on evidence concerning the costs, risks, and benefits of changes in major technological systems related to agriculture, health, water, energy, transportation, manufacturing, or construction, needed to support a growing world population. [Clarification Statement: For example, students construct arguments concerning the costs and benefits of shifting from centralized to distributed energy generation systems or natural to genetically engineered crops.] [Assessment Boundary: Limited to relative comparison of costs and benefits of different technological changes.]

The performance expectations above were developed using the following elements from the NRC *A Framework for K – 12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical and empirical models.

- Plan and carry out investigations Individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure the investigation's design has controlled for them. (a)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Construct a counter-argument that is based in data and evidence that challenges another proposed argument (d)
- Criticize and evaluate arguments and design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (b)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (b)

Disciplinary Core Ideas

ETS2.A: Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). (a)
- Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (a)

ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World

- Modern civilization depends on major technological systems, including those related to agriculture, health, water, energy, transportation, manufacturing, construction, and communications. (d)
- Engineers continuously modify these technological systems by applying scientific and engineering knowledge and practices to increase benefits while decreasing costs and risks. (d)
- Widespread adoption of technological innovations often depends on market forces or other societal demands, but it may also be subject to evaluation by scientists and engineers and to eventual government regulation. (b)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated or that may build up over time to a level that requires attention or mitigation. (c)
- Analysis of costs, environmental impacts, risks and benefits, are critical aspects of decisions about technology use. (c)

Crosscutting Concepts

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(b)

Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (b),(c),(d)

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society *(continued)*	
Connections to other DCIs in this grade-level: **HS.ESS-CC, HS.ESS-HS, HS.LS.IRE, HS.LS.NSE, HS.PS-ER, HS.PS-NP, HS.ETS-ED**	
Articulation to DCIs across grade-levels: **MS.ETS-ETSS**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.8.8	Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
WHST.9	Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with Mathematics
MP.5	Use appropriate tools strategically
8.F	Define, evaluate, and compare functions.
S.ID	Summarize, represent, and interpret data on a single count or measurement variable
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies
F.BF	Build a function that models a relationship between two quantities
N-Q	Reason quantitatively and use units to solve problems
MP.4	Model with Mathematics.
A.CED	Create equations that describe numbers or relationships.